JOURNAL of the SOCIETY of MOTION PICTURE and TELEVISION ENGINEERS

In This Issue

President's Report

TV Random Noise

Color Densitometer

Three-Color Process

Screen Illumination Color

Industrial Sapphire

Projection Lamp

Standards Committee Report

JANUARY 1950

This issue of the *Journal* marks several changes of sufficient importance to justify our pausing to give them careful thought. It is the first issue in a new year — a year that begins the second half of the twentieth century. The years just past have witnessed the greatest growth in scientific achievement the world has ever known. We have all had some part in that growth. The years to come promise to outdo those gone, and we shall have our part in this future.

One such achievement is the motion picture, now at a state of perfection not even dreamed of at the turn of the century. And what of its future? To me it seems that we are approaching another turning point in the art just as we did some twenty years ago when sound became a commercial reality. The imminence of this coming change is due in part at least to the rapid growth of a new method of presenting scenes and people in action, capable of bringing motion pictures directly into the home, as well as directly into the theater. I refer of course to

Continued on inside back cover

Journal of the Society of Motion Picture and Television Engineers

VOLUME 54 JANUARY 1950 NUMBER 1

Report of the President........................EARL I. SPONABLE 3

Perception of Television Random Noise..............PIERRE MERTZ 8

An Improved Photomultiplier Tube Color Densitometer.............
MONROE H. SWEET 35

Color Measurement of Motion Picture Screen Illumination...........
R. E. HARRINGTON and F. T. BOWDITCH 63

Cinecolor Three-Color Process..............ALAN M. GUNDELFINGER 74

New Projection Lamp and Carbon-Feed Mechanism..J. K. ELDERKIN 87

Industrial Sapphire in Motion Picture Equipment...................
WALTER BACH and CHRIS WAGNER 95

Report of SMPE Standards Committee...........FRANK E. CARLSON 102

New American Standards.. 106

Z22.61-1949, American Standard Sound Focusing Test Film for 35-millimeter Motion Picture Sound Reproducers (Service Type)... 107

Z22.68-1949, American Standard Buzz-Track Test Film for 35-millimeter Motion Picture Sound Reproducers.................... 108

New Officers of the Society.. 109

Engineering Committees.. 111

1950 Nominations.. 113

Society Awards for 1950.. 113

Society Announcements.. 115

BOOK REVIEWS

Acoustic Measurements, by Leo L. Beranek. Reviewed by Harvey Fletcher. 117

Painting with Light, by John Alton. Reviewed by John W. Boyle........ 118

Feininger on Photography, by Andreas Feininger.........................
Reviewed by Lloyd E. Varden 118

The Complete Projectionist, by R. Howard Cricks.........................
Reviewed by Merle Chamberlin 119

Current Literature.. 120

New Products.. 121

Meetings of Other Societies.. 123

ARTHUR C. DOWNES, *Chairman*, Board of Editors — VICTOR H. ALLEN, *Editor* — NORWOOD L. SIMMONS, *Chairman*, Papers Committee

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Society of Motion Picture and Television Engineers

342 Madison Avenue, New York 17, N. Y., Tel. Mu 2-2185
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Report of the President

By EARL I. SPONABLE

Movietonews, Inc., New York, N.Y.

It is customary at this time for the President of the Society to submit his annual report, and to bring to your attention such matters as seem to him worthy of your consideration. First, I am glad to be able to report to you that the year 1949 has been filled with healthy activity on the part of the Society and has resulted in an even greater service to the motion picture industry than at any time in the past.

The total membership at this time is over 3000: a real credit to the Membership Committee which has brought in 280 new members since April 1 of this year. This number of new members has more than made up for an unusually high loss of previous members, due probably to the aftermath of the war and to changing business conditions. Among our membership are representatives from 48 foreign countries, including Canada and Mexico, and from each of our 48 states.

I am proud of the work done by our 38 standing committees in which 471 members are giving their time to help improve the industry through standardization, and in other important ways. Parenthetically, at this point I would like to say that we would welcome the assistance of any members who are not now serving on committees, and who would like to do so. I suggest they get in touch with the chairman of the committee in which they are interested.

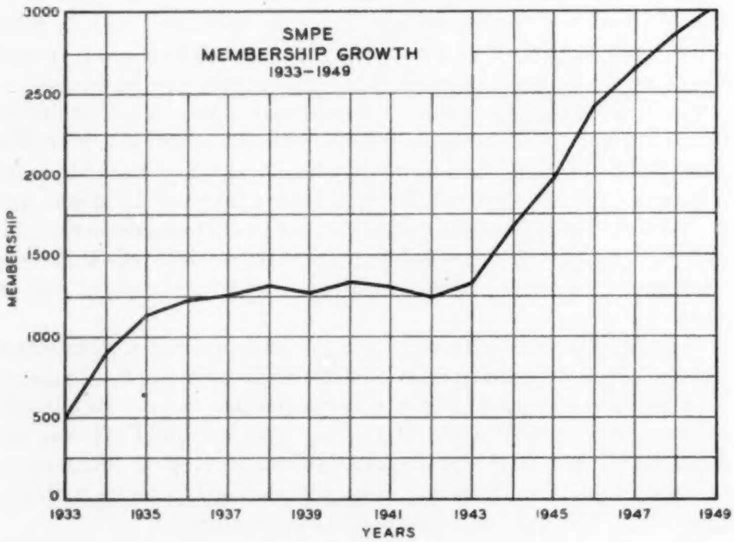
The Officers and Governors have been diligent in their jobs and most patient and helpful to me at Board Meetings. I want particularly to thank those men who are now finishing their terms of office and to urge them not to diminish their activity in Society affairs.

The general office is now well established at 342 Madison Avenue in New York City. The space, while not elaborate, has been adequate for our present needs. By the way of review, we have an efficient, small staff headed by Boyce Nemec, our Executive Secretary. The work of the engineering committees is handled by William H. Deacy, Jr., Staff Engineer; and Sigmund Muskat is the Office Manager.

Presented: October 10, 1949, at the SMPE Convention in Hollywood.

Improvement has been made in various office activities: The accounting system has been modernized; the committee work is being handled rapidly and efficiently; membership applications are being processed promptly; Journal publication has been speeded up; and our press relations are much improved.

Besides its own committee work, the Society now contributes to the support of, and has representation in, related organizations including the American Standards Association, the Inter-Society Color



Council, the United States National Committee of the International Commission on Illumination, the American Documentation Institute, and the National Fire Protection Association.

Our three local Sections have been unusually active during the current year. The chairmen and managers have arranged for papers that have commanded increased attendance. One highlight of the year was the joint meeting of the New York and Chicago Sections through the use of inter-city television, dealing with "A Study of Television Lighting." The combined attendance at this one meeting exceeded 1000 and resulted in important publicity and improved public relations for the Society.

The 65th Semiannual Convention, held this past spring in New York City, was an outstanding success. Its theme of television attracted an all-time record registration of 715. This current Convention, the Society's 66th, also has a program of great interest that has been made possible by most diligent work on the part of the Program and Local Arrangements Committees. I am sure that this Hollywood Convention will be one that we all shall remember as an enlightening experience.

Printing costs have gone up along with everything else. This has led to a study of the format of the JOURNAL, and designing it to use the available space more efficiently. Careful planning is in progress in co-operation with the Society's printer to effect a transition to a somewhat new dress wherein we may use for the most part a two-column page and achieve better readability and more text material per page, at practically no increase in cost.

During the year the Society published a book on theater engineering entitled *The Motion Picture Theater*, with which I believe most of you are familiar. In spite of a carefully worked out plan for sales we have not received the number of orders we anticipated. I believe, however, that an important reference book such as this will be in demand for some time to come. Our other less ambitious publications in the form of monographs entitled "Films in Television," "Theater Television," "High-Speed Photography," and "Color Symposium" were well received, have paid their costs, and have helped to gain the Society recognition in their respective fields.

The Society has continued its service of making and supplying test films. New films this year include a 16-mm sound service test film, and a television visual test film. Both of these films are very much needed in the industry. They will be described and samples will be shown at this meeting.

A number of new standards have been approved during the current year, and have been published in the JOURNAL. Also, the Board of Governors has authorized the publication from time to time of special reports to be known as "SMPE Recommendations." While these Recommendations have not reached the stage of standards, they will have been approved by engineering committees and the Engineering Vice-President and should be a useful guide to equipment manufacturers. They will be printed to fit the standards cover, but colored paper will be used to distinguish them from adopted standards.

The financial position of the Society, while on a sound basis at present, requires careful watching. Our expenditures and receipts run about $125,000 per year. The year 1948 ended with a deficit of $8,724. This was partly due to non-repetitive expenses such as furniture for new offices. This year the indications are that we will nearly break even. Our net quick assets are over $90,000. Largely through the efforts of Don Hyndman we have materially increased our income from sustaining members. In 1945, income from this source was $8,087, was brought up to $20,250 in 1946, and this year it will total over $24,000. If we are to continue to expand our service to the industry it is obvious that our income must keep in step. Every possible source of revenue will be studied carefully and every effort made to keep our operating costs as low as is consistent with our program of service.

Never in the history of this Society has it had the standing, or commanded the respect of the leaders in the motion picture industry, that it does today. This is no mere accident, but rather is the cumulative result of teamwork among all its members. The pioneer work in theater television, largely due to the efforts of Paul Larsen and a few others, is beginning to be recognized. The recent Society answer to the request of the Federal Communications Commission for advice regarding theater television (which will be reported on later at this meeting by Don Hyndman) is an example of what I mean. Likewise, the Theatre Owners of America and the Motion Picture Association have sought our advice in this same matter. We must carry on and justify the confidence that has been placed with us to do the proper engineering job and to give technical guidance, not only to the motion picture industry as it is now constituted, but also to the new, closely allied art of television.

This brings me to our plans for the future. Our Past President, Loren Ryder, has emphasized over and over that the scope of the Society activities includes all phases of pictorial rendition of action. With this I am in hearty accord. We are concerned with television whether we all like it or not. While television did not develop within the motion picture industry and while credit for its conception and growth belongs to the electronic and radio engineers, there is, nevertheless, a very large area of common interest in the two fields. The vast accumulation of knowledge of production problems, lighting, photography, sound recording, film handling, and projection technique are all parts of this common area; and this accumulated knowl-

edge of the membership of this Society represents such values to the growing television art that the television engineer will find himself able to acquire this information in only one of two ways: either by arduous, costly, personal experience, or alternatively, by becoming a member of this Society. We have, therefore, much incentive to offer to the television engineer to join with us; and on our side, there is much to be gained by this union, both from the point of view of society economics and from that of service to the industry. It is for these basic reasons that your Board, after due committee consideration, decided to recommend to the membership that the name of the Society be changed to "Society of Motion Picture and Television Engineers," and that the founders and developers of this new allied art be actively encouraged to take part with us in developing a larger and more effective service. It is my sincere personal belief that such a change will profit the Society and the industry, and I hope that with your enthusiastic support of the enlarged program which I have just outlined, time will prove the wisdom of this course.

Perception of Television Random Noise

By PIERRE MERTZ

Bell Telephone Laboratories, New York, N.Y.

Summary—**The perception of random noise in television has been clarified by studying its analogy to graininess in photography. In a television image the individual random noise grains are assumed analogous to photographic grains. Effective random noise power is obtained by cumulating and weighting actual noise powers over the video frequencies with a weighting function diminishing from unity toward increasing frequencies. These check reasonably well with preliminary experiments. The paper includes an analysis of the effect of changing the tone rendering and contrast of the television image.**

The accumulation of data for guidance on tolerances to be placed on random noise in circuits used for television transmission has developed a fairly large number of parameters that cannot be neglected if the interpretation of these data is to be useful.[1] Among these parameters are some which concern the phenomena involved in the perception of the noise by the viewer. There is presented herewith a discussion of some of these phenomena.

The treatment covers several of the parameters, but it cannot presume to solve completely the problem of tolerances. It constitutes merely a first order attack on the major quantities involved.

The discussion is divided into three parts: (1) factors involving the granular appearance of the random noise; (2) factors involving the perception of adjacent differences in luminance; and (3) factors involving the translation of signal voltages into image luminances.

1. Influence of Granular Appearance

Certain phenomena in the perception of random noise have been clarified by studying its analogy to the effect of graininess in a photographic image.

Long study of photographic graininess[2] indicates that the perception of graininess involves two parameters of the emulsion:

1. The extent of the density variations in the emulsion caused by the grains;

2. The average size of the individual grains.

Presented: October 14, 1949, at the SMPE Convention in Hollywood.

List of Symbols

a	=	a constant
A	=	a constant, in one case being the constant area of a microdensitometer aperture
b	=	a constant, in one case being a characterization of the "key" of a picture
B	=	luminance, average picture luminance over an area
B_A	=	adaptation luminance (millilamberts)
B_B	=	luminance of test field (millilamberts)
B_S	=	maximum luminance in surround field (millilamberts)
$B(\theta, \varphi)$	=	luminance of surround field over elementary solid angle $d\omega$
c	=	a constant
D	=	ratio of actual viewing distance to a picture, to four times picture height
f	=	frequency
f_e	=	effective frequency
f_o	=	upper cutoff frequency of low pass filter
g	=	quantity evaluating appearance of graininess
k	=	proportionality constant
K	=	a constant, in one case a constant speed of scanning beam
n	=	a number, in one case used as exponent, in another, an average number of photographic grains per unit area
N	=	number of television scanning lines in picture height
p, q	=	constants
r	=	response of eye to granular luminance deviations
s	=	index of graininess in photographic emulsion
S	=	sensation (evaluated in number of perceptible steps)
T	=	time taken by scanning or reproducing beam in sweeping across assumed sampling area when $D = 1$
u	=	number of television scanning lines in sampling area height
v	=	average number of noise spots per segment of scanning line across sampling area
V	=	signal voltage
W	=	mean square of luminance deviations (or "power") of random "noise"
W_e	=	effective square of luminance deviations (or "power") of random "noise"
W_1	=	"power" at threshold for "flat noise"
W_2	=	"power" at threshold for "up-tilted noise"
$W(f)$	=	mean square of luminance deviations (or "power") of random "noise" in unit frequency band at frequency f
δB	=	rms of luminance departures from average, in a portion of the picture area
Δb	=	increment in luminance, measured in effective photographic density units
ΔB	=	increment in luminance, measured in millilamberts
Δv	=	increment in signal, measured in decibels
ΔV	=	increment in signal, measured in volts
φ	=	angle measured about line of sight to a test field
θ	=	angle in radians between line of sight to an elementary spot $d\omega$ and line of sight to a test field
σ_1	=	rms departure from average in microdensitometer density measurement (idealized aperture)
σ_2	=	rms departure from average in microdensitometer density measurement (actual aperture)
$d\omega$	=	elementary solid angle in steradians

The graininess of a photographic emulsion is measured by exploring an arbitrary path over a region of it having constant average density over the gross parts of the region. This is carried out with a microdensitometer having a sampling aperture which is small but of suffi-

cient area to include a number of grain clumps simultaneously. From the microdensitometer record there is determined the root mean square deviation of the density about the mean.

A highly schematic illustration of this process is shown in Fig. 1. The sampling aperture is shown in one position along the path. It is shown square rather than with the usual round form to simplify some later discussion.

The microdensitometer readings will vary according to the size of the aperture used. In Fig. 2 an illustrative trace of the density is

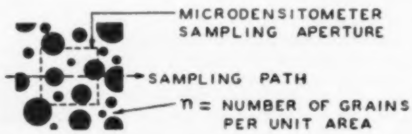


Fig. 1. Scheme of microdensitometer sampling.

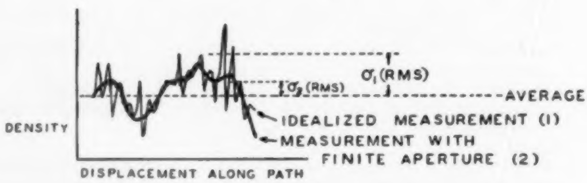


Fig. 2. Example of density readings.

compared with an idealized measurement made with an infinitesimal aperture. The ratio of the rms departures (σ_1 and σ_2) in density is approximately equal to the square root of the number of grains included in the aperture, thus

$$\sigma_1/\sigma_2 = \sqrt{nA} \tag{1}$$

where n = average number of grains per unit area;
A = area of effective aperture, measured on emulsion.

Hence in correlating measurements made with different apertures on the same emulsion, a constant quantity is the product of the rms density measurement by the square root of the aperture area. This is indicated as equal to the idealized rms density measurement divided by the square root of the number of grains per unit area.

$$s = \sigma_1/\sqrt{n} = \sigma_2\sqrt{A} \tag{2}$$

This quantity is here called s, and used as an index of the graininess of the emulsion.

When the emulsion is viewed by the eye, a less definite but similar sampling aperture comes into play. This is caused by the limited resolving power of the eye, instead of the microdensitometer. The appearance of graininess, or evaluation by the eye of the quantity σ_2, is then equal to the quantity s divided by the square root of the sampling area. This new quantity is called g.

$$g = \sigma_2 = s/\sqrt{A} \tag{3}$$

The sampling area subtends a constant solid angle at the observer's eye as the viewing distance is changed. Thus at the greater viewing distances the area A on the emulsion increases, and the appearance of graininess is reduced.

In a television image the individual random noise grains are assumed as analogous to the photographic grains. The sampling area again subtends a constant solid angle at the observer's eye. The number of noise grains in this area is proportional to the product of the number of scanning lines in the area by the average number of grains in the portion of a scanning line included in the area. This last number can be computed if desired from a formula published by S. O. Rice[3] for the average number of zeros per second in random noise.

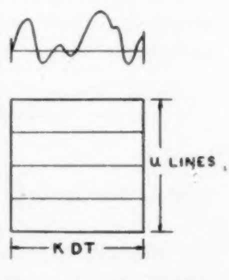


Fig. 3. Television sampling area.

It is found, however, that in television there is correlation between noise grains along a scanning line, according to the particular noise power distribution in the frequency spectrum. This is a fact which does not figure in the photographic analogy. In consequence the analogous appearance of graininess for the television must be computed in a slightly different manner.

A sampling area is illustrated in Fig. 3. A distribution of luminances along one scanning line is illustrated at the top. For small departures the deviation in luminance is nearly proportional to the negative of the deviation in density. The average response of a photocell over such a sampling interval of scanning line is known from scanning theory,[4] and is taken as analogous for the eye. Each Fourier component in the trace is attenuated by a weighting function characteristic of the sampling aperture or interval. In this case the sampling inter-

val will be assumed rectangular, of duration DT. D is a factor weighting viewing distance, which at four times picture height is taken equal to one, i.e.,

$$D = \frac{\text{viewing distance}}{4 \times \text{picture height}}.$$

T represents the time taken by the reproducing beam in sweeping across the sampling area when $D = 1$. The width of the sampling area on the picture screen is KDT, where K is the speed of the beam.

The "power" response, using this in the sense merely of the output of the photocell analogous to the eye, of a single scanning line trace, is given by

$$r^2 = \int_0^\infty W(f)\ [\sin \pi fDT/(\pi fDT)]^2\, df. \tag{4}$$

The correlation which exists between noise grains along the scanning line in the sampling area drops to zero between scanning lines. Thus the square of the rms luminance deviation (or the "response power") averaged over the number u of scanning lines in the sampling area height is, as in the photographic case, the square of the rms deviation (or "response power") over one line divided by u or kDN.

Here N = number of scanning lines in picture height;
k = proportionality constant.

With all the constants adjusted to give 1 at $D = 1$, the effective noise power response is given by.

$$W_e = r^2/D = (1/D)\int^\infty W(f)\ [\sin \pi fDT/(\pi fDT)]^2\, df. \tag{5}$$

Thus the effective random noise power is obtained by weighting and cumulating actual noise powers at the various video frequencies with a weighting function. This function diminishes from unity toward increasing frequencies approximately like the weighting function of a scanning aperture. Following this theory, then, one would expect threshold of perception to be obtained at a fixed effective random noise power for all distributions of the random noise.

The theory can be checked with some preliminary unpublished experimental data taken by M. W. Baldwin on the near threshold values of various distributions of television random noise, viewed at several distances. The twelve distributions experimented with are illustrated

in Fig. 4. "Flat" means a distribution which is substantially flat up to cutoff. "Up-tilted" means one in which rms amplitude in a narrow frequency band is proportional to the center frequency of that band up to the region of cutoff. "Coaxial" is a distribution which is expected in some hypothetical coaxial system designs. These noise distributions were viewed at distances $D = 0.625$, 1.0, and 2.0, respectively. The near threshold values of total measured random noise in each case as a function of upper cutoff frequency are indicated by the connected points in Fig. 5. The noise is measured in terms of the ratio of the rms of luminance departures δB, to the average luminance

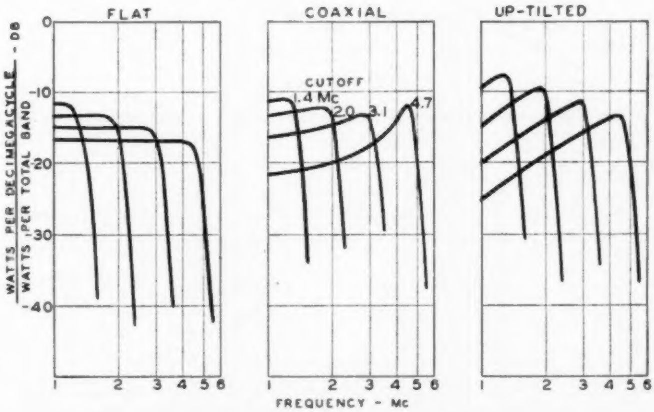


Fig. 4. Experimental random noise distributions.

$\overline{B}$. The logarithm of this is taken, as if db were used to represent an amplitude ratio. The quantity has sometimes been called "decilums."

In fitting equation (5) to these data it is necessary to choose a value for the sampling interval T. As will be indicated further below, this has been selected for the best fit at $T = 0.22$ microsecond. With this value the weighting functions for the three distances are shown by the curved lines in Fig. 6. The fit of the computation of equation (5) with experimental data under these conditions is shown by the curved lines in Fig. 5.

The fit is not perfect, but is considered reasonably good. The greatest discrepancies in trend seem to come at the shortest viewing distance. This suggests that the noise distributions which have been

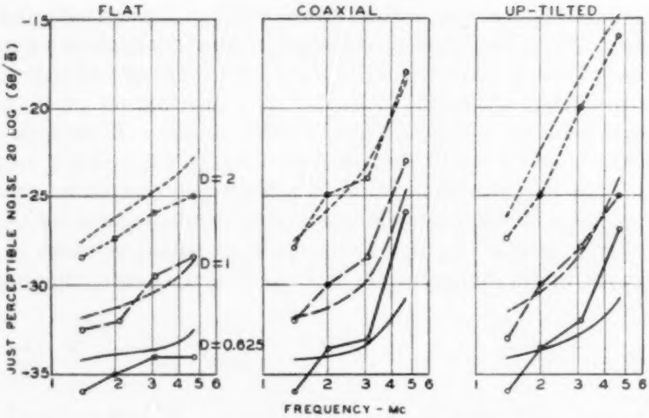


Fig. 5. Noise perception with distributions of Fig. 4; comparison with theory.

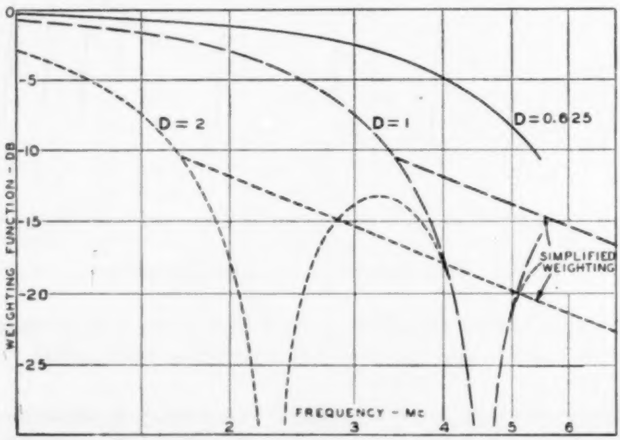


Fig. 6. Hypothetical visual weighting of noise.

shown in Fig. 4 are modified by the filtering effect of the picture tube electron beam spot before being viewed by the observer. The exact distribution of luminance in the spot is not known, but a computation of the filtering effect is shown in Fig. 7 on the assumption that the distribution follows a cosine squared law of such width as to come to zero weighting at 10 Mc.

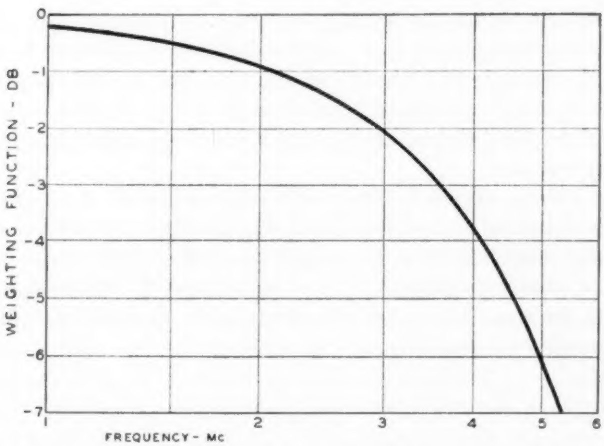


Fig. 7. Hypothetical filter effect of receiving cathode ray spot.

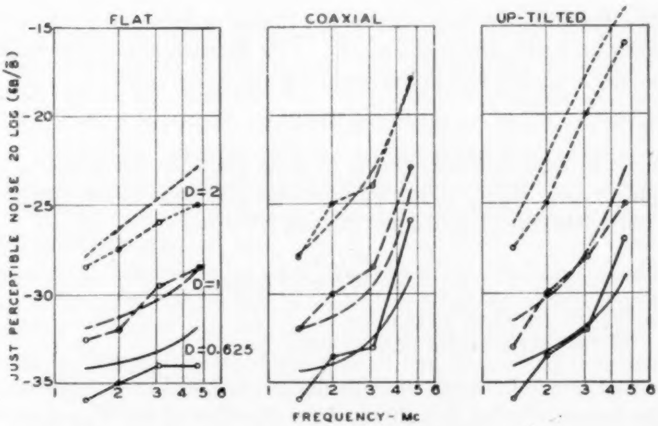


Fig. 8. Noise perception with distributions of Fig. 4; comparison with theory corrected by Fig. 7.

With this correction the experimental data are fitted as shown in Fig. 8. The fit is somewhat better than in Fig. 5, and the worst residual discrepancy is reduced to 3 db.

It would be expected that the law derived from analogy with photographic graininess should break down at very low frequencies because

the granularity in the horizontal direction then extends well beyond any reasonable sampling area. Such a breakdown has been found to exist in the case of narrow band distributions of noise well under 1 Mc. The low-frequency region and distributions under which the law appears invalid seem narrow enough not to be of too much consequence in its general use.

There is some interest in returning to the evaluation of the response from the sampling area of Fig. 3 and disregarding the correlation between noise grains along a scanning line. As noted above this can be done from Rice's treatment.[3] It can be assumed for the present purpose that the noise has an "effective frequency" f_e, which is defined as half the number of zeros per second.

Then

$$f_e^2 = \frac{\int^{\infty} f^2 W(f)\, df}{\int^{\infty} W(f)\, df}. \tag{6}$$

Thus the effective frequency is the radius of gyration of the power distribution figure about the y axis. The average number of spots of noise v per scanning line in the sampling area is equal to:

$$v = DTf_e\,. \tag{7}$$

Thus the total average number of noise grains in the sampling area is equal to uv. Hence following equation (1), but writing powers instead of density departures, and placing $na = uv$,

$$\begin{aligned} W_e &= W/(uv) \\ &= W/(kNTD^2 f_e), \end{aligned} \tag{8}$$

where W_e = effective noise power;
W = actual total noise power.

Several simple laws can be immediately deduced from equation (8). As the distance factor D is changed the effective power W_e varies with the inverse square of the distance. Thus fixing W_e at a point corresponding to threshold gives a variation of W with the square of the distance, or an increase of 6 db with every doubling of the distance. This law is found to hold roughly with the data presented in Figs. 5 and 8. The simplicity of the law is lost in the more accurate formula of equation (5).

For the case of the flat noise distribution to an upper cutoff f_a, equation (6) becomes:

$$f_e = f_c/\sqrt{3}\,. \tag{9}$$

Also

$$W = f_c W(f)\,. \tag{10}$$

From equation (8),

$$\begin{aligned} W_e = cW/f_e &= cf_c W(f)(\sqrt{3}/f_c) \\ &= c\sqrt{3}W(f), \end{aligned} \tag{11}$$

where c = a constant, and the threshold of visibility of the noise is independent of the cutoff frequency f_c when the power per cycle, $W(f)$, is kept constant. This law appeared rather startling when first discovered experimentally by M. W. Baldwin in tests similar to those plotted in Figs. 5 and 8. It means that as noise is added by raising the cutoff frequency of a flat distribution, the masking effect of the additional fine grained noise exactly compensates for the increased noise amplitude, to keep the perception at a constant. The law is approximately followed by the data for the flat distribution in Figs. 5 and 8, where it would be represented by lines of 6 db per octave slope. The simplicity of the law is again lost in the formula of equation (5). The reality of the correlation which forms the basis for equation (5) is, however, shown by the data for the up-tilted distribution in Figs. 5 and 8. When the correlation is ignored, an equation similar to equation (11) is obtained, plotted with a slope of 6 db per octave in Figs. 5 and 8. The actual data, however, show a distinctly steeper slope, which is reasonably well indicated by equation (5).

Actually the differences between the data for the flat and up-tilted distributions can be used to give a sensitive evaluation of the sampling interval DT. If W_1 and W_2 are respectively the total powers at threshold for flat and up-tilted noise up to the same cutoff frequency, the ratio of these, from equations (6) and (8), is:

$$W_2/W_1 = 3/\sqrt{5} \qquad (1.3\text{ db}). \tag{12}$$

From equation (5) the ratio is approximately:

$$W_2/W_1 \approx \pi^2 f_c DT/3. \tag{13}$$

A plot of the data, equation (12), and the best fit for equation (13), are shown in Fig. 9. The value of T is obtained from this best fit for example at the point where W_2/W_1 equals $\pi^2/3$ or 5.17 db. Here $T = 1/(f_c D) = 1/4.55 = 0.22$ microsecond. The plot of W_2/W_1 from

equation (5) without the simplifications of equation (13) is also shown in Fig. 9.

It seems doubtful that the sampling area should be so sharply defined in the eye as to give a weighting function with the deep minima shown by the curved lines in Fig. 6. Some exploration has accordingly been carried out of a weighting function which starts out at low frequencies with the curves of Fig. 6, but which before the minima are reached translates to straight lines as shown. The differences which

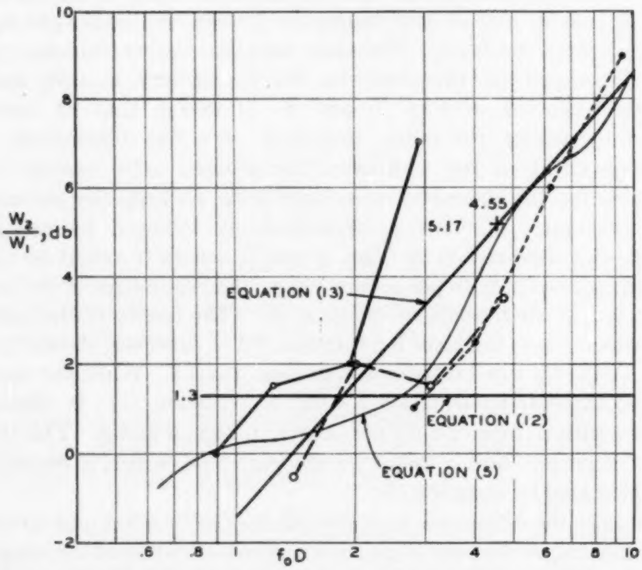


Fig. 9. Difference in perception between flat and up-tilted noise.

result from this in the particular comparisons of Figs. 5 and 8, are well under 1 db. The simpler form of weighting function appears practical, though later checks with narrower distributions of noise are desirable.

The value of *DT* which has been determined corresponds to 4.8 minutes of arc at the observer's eye. The sampling area is therefore larger, on a side, than the conventional one minute of arc of visual acuity. This is not unreasonable, inasmuch as the one minute figure is obtained with substantially 100 per cent contrast, while here the sampling area merges noise grains under near threshold conditions,

where the typical contrast is substantially less. It can be expected from this that the sampling area may vary in size from threshold conditions to random noise much above threshold. This is confirmed by the experimental viewing of fields of wide-band random noise. As the noise is reduced in amplitude to approach threshold, the characteristic granular form of the noise perceived at the higher intensities yields to larger floating nebulous masses.

2. Perception of Luminance Differences

The threshold of perception of the difference in luminance between two adjacent areas is characterized, over a range, by a constant ratio of the difference in luminances to the greater of the two. This is known as the "Weber-Fechner law."[5] This threshold difference was further interpreted by Fechner as an elementary sensation step, thus

$$dS = dB/B. \tag{14}$$

The ratio on the right-hand side is known as the "Fechner fraction." The expression may be integrated, as

$$S = \log B + \text{constant.} \tag{15}$$

The range of validity of the Weber-Fechner law and the deviations from it outside this range have been the subject of much experiment. A general summary of some of this work has recently been presented by Moon and Spencer.[6]

This paper considers particularly two phases of the departures. The first is a gradual rise in the value of the threshold Fechner fraction toward lower luminances of the field. This is generally well known, and it is obvious that it must occur because at the threshold of perception the luminance perceived can just be distinguished from physical black, and the value of the Fechner fraction is therefore 1. Luminances just below this, hence, appear as "subjective black," and the threshold luminance gives the boundary of subjective black.

The second phase consists in the influence of glare light from a surrounding field. This is of great practical importance in daily vision and in the viewing of a picture, because the area being concentrated upon is almost never surrounded by substantial darkness. The treatment of this phase of the problem is much simplified by the "Holladay principle," which gives a weighting formula establishing the equivalence of any glare field distribution to a total field of constant luminance, which last is then called the "adaptation luminance."

This formula is:

$$B_A = 0.923\ B_B + (K/\pi)\int B(\theta,\ \varphi)\theta^{-2} \cos\theta\ d\omega = aB_B + bB_S, \quad (16)$$

where B_A = adaptation luminance in millilamberts;
B_B = luminance of test field in millilamberts;
B_S = maximum luminance existing in surround field, in millilamberts;
$B(\theta,\ \varphi)$ = luminance of surround field over elementary solid angle $d\omega$;
θ = angle in radians between line of sight to elementary spot $d\omega$ and line of sight to test field;
φ = angle measured about line of sight to test field;
$d\omega$ = elementary solid angle in steradians;
K = a constant = 9.6×10^{-3};
a, b = constants.

The formula assumes a test field of a diameter subtending an angle of 1.5 degrees (.026 radians) at the eye. This is illustrated by the field II in Fig. 10.

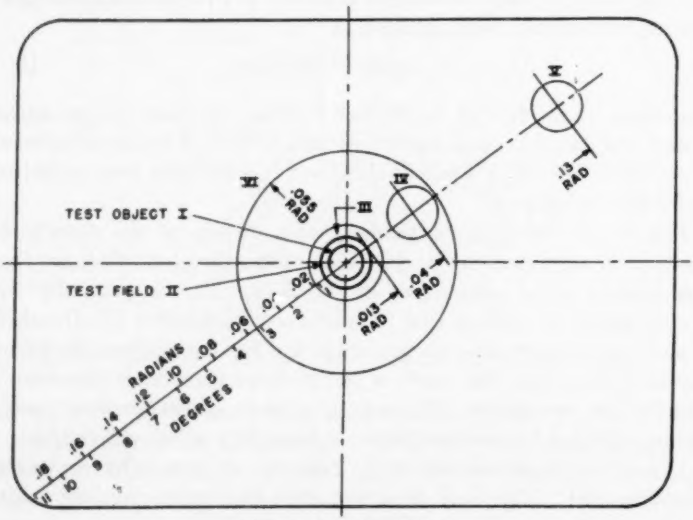


Fig. 10. Picture field.

The first equation assigns to a in the second equation a fixed value 0.923. The quantity b is a parameter measuring the character of the distribution of luminances in the surround field. It assumes its maximum value, namely 0.077, for a complete surround all at the lumi-

nance of the test field B_B. It approaches its minimum value of zero for a surround which is all physically black except for a small area of luminance B_S, and the value further falls rapidly as this area is removed from the line of sight. Some intermediate fields are illustrated in Fig. 10.

The value of b is 0.05 for a field of luminance B_S entirely surrounding the circle VI, the space within this, to the test field boundary, being physically black. Single areas of luminance B_S at the spots III, IV, and V give values of b respectively 0.01, 0.001, and 0.0001. Fig. 10 also shows the outline of a picture field, viewed at $D = 1$ with aspect ratio of 3 (height) to 4 (width).

Moon and Spencer specify the luminance of a test object enough lower than that of the test field to be just perceptible, and tell how this is influenced by the adaptation luminance. The test object subtends an angle of one degree, indicated by field I in Fig. 10. The formula breaks up into two cases according to whether the adaptation luminance is greater or less than the test field luminance.

In the first case, where

$$B_A = aB_B + bB_S \geqq B_B, \tag{17}$$

the threshold is reached at a value indicated by the empirical equation

$$B_B - B_o = \Delta B = c\,(A + \sqrt{aB_B + bB_S})^2, \tag{18}$$

where B_o = luminance of test object in millilamberts;
A = a constant = 0.255;
c = a constant = 0.143.

In the second case, where

$$B_A = aB_B + bB_S < B_B, \tag{19}$$

$$\Delta B = c\left[A + \frac{B_B}{\sqrt{aB_B + bB_S}}\right]^2 \tag{20}$$

A plot of the formula is illustrated in Fig. 11 in terms of the Fechner fraction (that is, $\Delta B/B$) as a function of the luminance B_B of the test field, for a variety of values of bB_S. The curves are in general given for integral powers of 10 for bB_S, but in one case b is given its maximum value (0.077) for a maximum surround luminance B_S = 10,000 millilamberts. The asymptotic value reached for $bB_S = 0$ is also illustrated.

As in the case of the Weber-Fechner law, it is possible to integrate the Moon and Spencer formula to obtain the total cumulation of perceptible steps in luminance, say from some maximum luminance

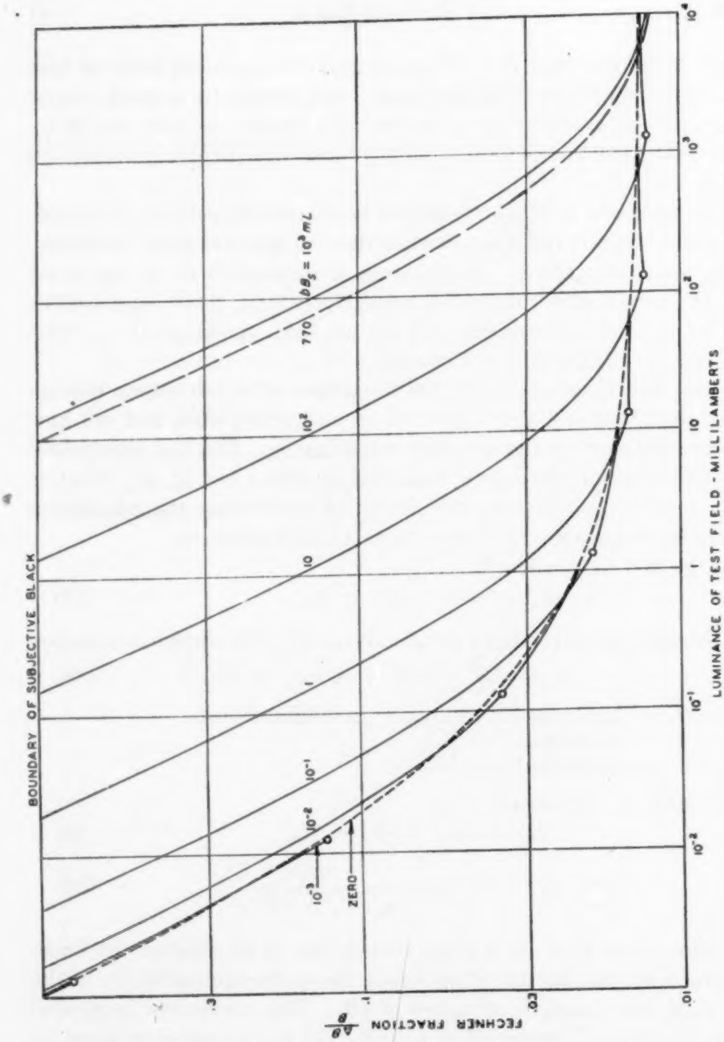


Fig. 11. Moon and Spencer formula for deviations from Weber-Fechner law.

of the test field B_B down to a lower specified value. This may be done by taking the approximate relationship

$$\frac{dS}{dB} = \frac{\Delta S}{\Delta B} \tag{21}$$

and putting $\Delta S = 1$ (to represent a single step), and by expressing

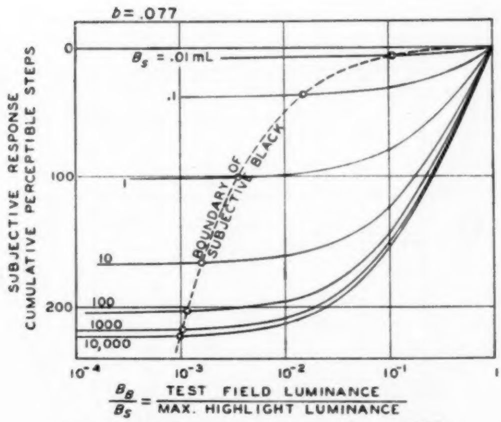


Fig. 12. Subjective Response (b = .077).

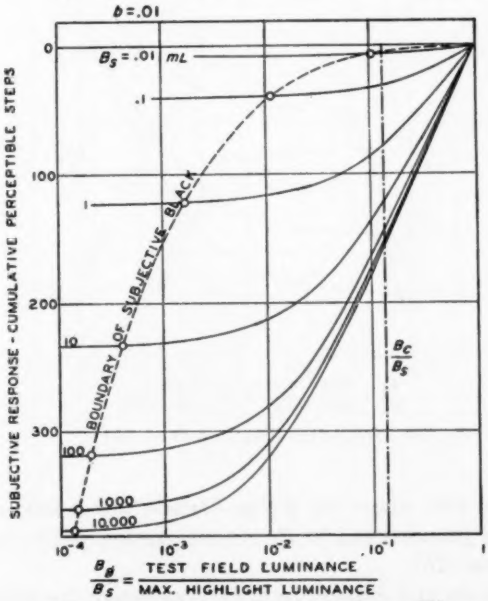


Fig. 13. Subjective Response (b = .01).

ΔB as a function of B_B from equations (18) and (20). Formally, this leads to:

$$S = \int dS = \int \frac{1}{\Delta B}\, dB = \int \frac{dB_B}{\Delta B(B_B)} \cdot \qquad (22)$$

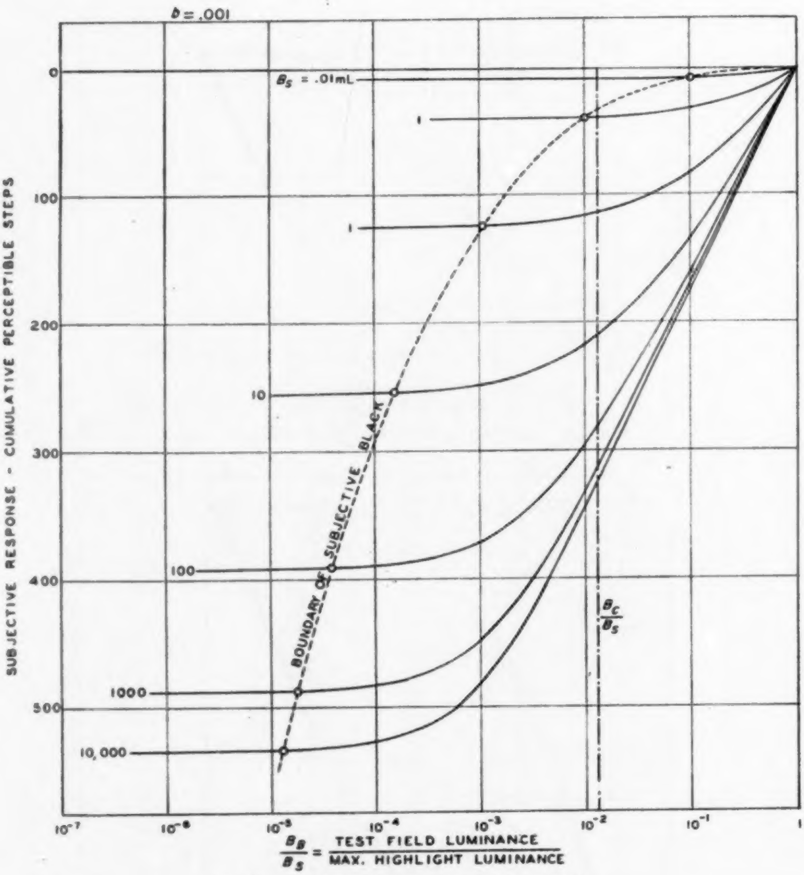


Fig. 14. Subjective Response (b = .001).

In the simpler case where the Weber-Fechner law is followed, that is, where ΔB is proportional to B, the integration yields the result given in equation (15).

Where the Moon and Spencer formula is assumed, the appropriate expression from equations (18) and (20) is introduced in the integrand. In this instance, the integration is rather laborious but straightforward. The results have been plotted in Figs. 12 to 15, inclusive, each plot being for a different assumed value of the parameter b. Each plot shows the cumulative perceptible steps from the maximum luminance value B_S in the field, down to a specified ratio B_B/B_S

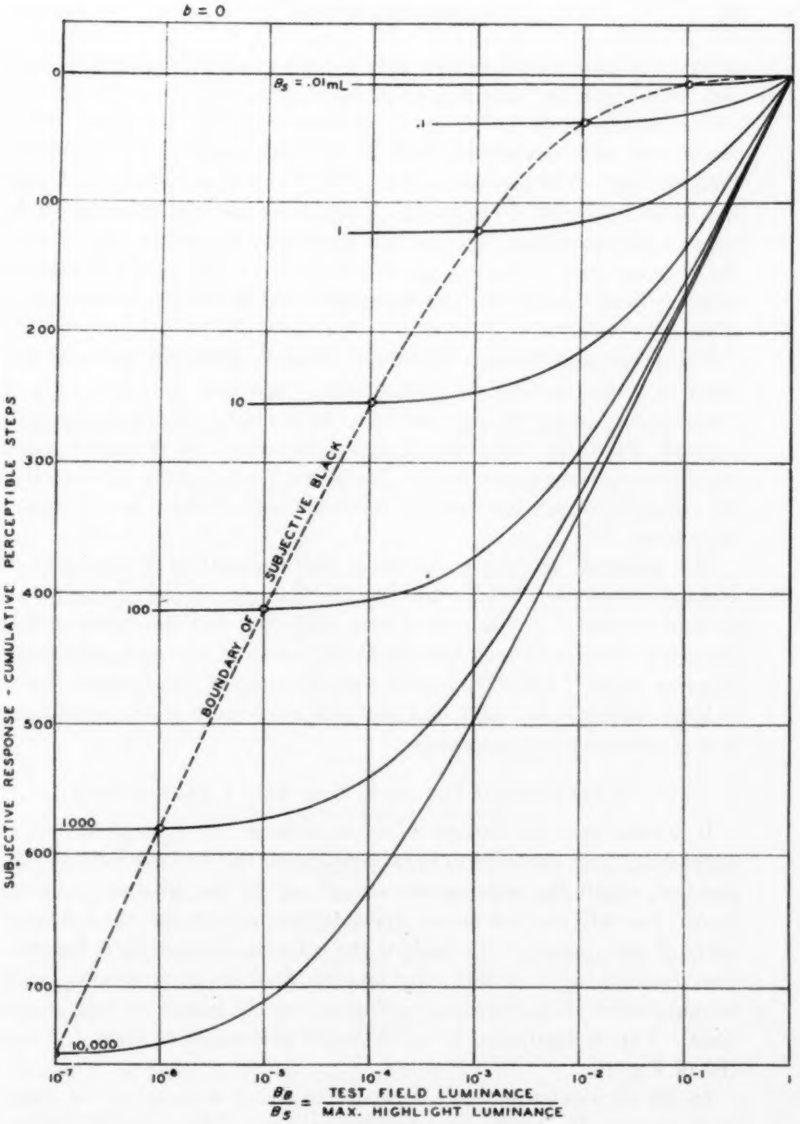


Fig. 15. Subjective Response ($b = 0$).

of this, for a variety of values of B_S as indicated. The plot is continued in each case to the approximate boundary of subjective black.

The curves from the Moon and Spencer formula have been compared with other determinations of the deviations from the Weber-Fechner law.[7] The agreement is not always too satisfactory, although this is undoubtedly in part caused by differences in viewing conditions, which are quite varied. In a general way, one can say that in the present state of knowledge the form of the formula proposed is reasonably adequate, but the constants used in it may be subject to some later revision.

The Moon and Spencer formula represents an important step forward in understanding the perception of contrast in the viewing of scenes and images. It, together with the Holladay principle, traces in a simple form the variations in this perception with picture content and highlight luminance level. The general qualitative facts of this are common knowledge, but the formula presents them in a compact expression.

The formula, of course, describes the perception of contrasts of areas of about photometric size, rather than grains of the size found in random noise. It has been found, however, that the vision of fine lines and areas is largely describable in terms of contrast perception in larger areas.[8] Thus the information on areas of photometric size is at least illustratively valid, and probably even more, in the consideration of random noise perception.

3. Influence of Signal to Luminance Translation

It is clear that the susceptibility to noise in the over-all system is dependent only upon the characteristics of the system beyond the point at which the noise is introduced, up to the ultimate viewing. Hence the only portion of the characteristic influencing the susceptibility of the system to the noise is the transfer characteristic between the electrical signal at this point and the final image luminance, with the subjective characteristics appropriate to the image viewing conditions. This is illustrated in two forms of presentation, parts (A) and (B) of Fig. 16.

In (B) the electrical signal is plotted in terms of db below the maximum signal. In (A) the electrical signal is plotted as the arithmetical ratio to the maximum signal. The luminance is plotted, in both cases, in terms of a hypothetical photographic density by which maximum

highlight luminance in the picture is attenuated, to equal the given luminance.

In (A) if a noise impulse is superposed on a given signal c, it increases it to d. The increment in signal, called ΔV, leads to an increment in luminance (measured in density units) called Δb. A given increment or decrement in voltage throughout the signal range appears as a constant displacement in the plot, represented by the two dotted lines.

In plot (B), on the other hand, a modulation of the signal which increases its level by Δv (measured in decibels), raises it from f to g, leading to an increment in the luminance from g to h, or Δb (measured

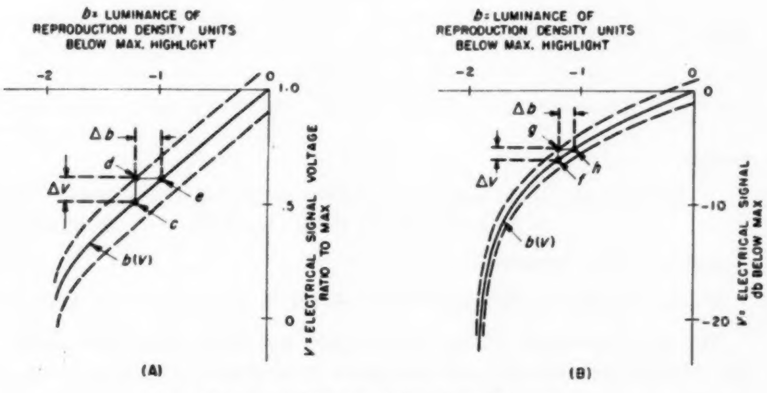


Fig. 16. Characteristic of reproducer.

in density units). This modulation, over the signal range, appears as a constant increment (or decrement if in the reverse direction), and is again represented by two dotted lines.

That is, additive noise leads to luminance changes (in density units),

$$\Delta b = (db/dV)\,\Delta V, \tag{23}$$

where ΔV = noise-to-signal amplitude ratio.

Modulation leads to similar luminance changes,

$$\Delta b = (db/dv)\,\Delta v, \tag{24}$$

where Δv = modulation (from undistorted signal) in decibels.

The quantities db/dV and db/dv are seen to be important in translating the respective electrical disturbances into image disturbances.[9] The first, namely db/dV, times a factor which will be explained, has been called the "interference sensitivity" of the reproducer. It is sometimes desirable to express equation (23) in logarithmic terms. It becomes

$$20 \log_{10}(\Delta b) = 20 \log_{10}(db/dV) + 20 \log_{10}(\Delta V). \qquad (25)$$

The last term on the right is now the noise-to-signal ratio in db. The term on the left can be rewritten in terms of the Fechner fraction $\Delta B/B$ as:

$$\Delta b = 0.4343 \ \Delta B/B$$

and

$$\frac{20 \ \Delta b}{8.686} = \frac{\Delta B}{B}.$$

Hence

$$\begin{aligned} 20 \log_{10}(\Delta b) &= 20 \log_{10}(20 \Delta b/8.686) - 20 \log_{10}(20/8.686) \\ &= 20 \log_{10}(\Delta B/B) - 20 \log_{10} 2.30 \qquad (26) \end{aligned}$$

Equation (25) becomes:

$$20 \log_{10}(\Delta B/B) = 20 \log_{10}(db/dV) + 7.2 + 20 \log_{10}(\Delta V). \qquad (27)$$

The first two terms on the right, taken together, have been called the "interference sensitivity" measured in decibels. The term on the left is a measure of the Fechner fraction in decilums, as used in Figs. 5 and 8.

In an entirely analogous way, equation (24) can also be expressed in logarithmic terms. It becomes:

$$20 \log_{10}(\Delta b) = 20 \log_{10}(db/dv) + 20 \log_{10}(\Delta v). \qquad (28)$$

The last term on the right can be expressed with respect to $\Delta V/V$ as follows:

$$\Delta v = 8.686 \ \Delta V/V$$

or

$$20 \log_{10}(\Delta v) = 20 \log_{10}(\Delta V/V) + 18.8.$$

Hence the entire equation becomes:

$$20 \log_{10}(\Delta B/B) = 20 \log_{10}(db/dv) + 26.0 + 20 \log_{10}(\Delta V/V). \qquad (29)$$

The last term on the right now expresses how far below the signal, in decibels, is the modulation. The first two terms on the right, taken together, have been termed the "differential sensitivity" in decibels. The quantity on the left, as before, is a measure of the Fechner fraction in decilums.

The interference and differential sensitivities are presented for several elementary picture tube characteristics in Fig. 17. For three of those shown, the luminance of the reproduction varies as some power n of the input signal voltage. For the fourth, the luminance varies as the exponential of the voltage.

In order for comparisons between the four to be more meaningful, they have been so chosen that the signal voltage covers the same range, and gives the same finite luminance range (two photographic density units), for all the characteristics. This requires adding a small bias in some cases to the voltage, otherwise to zero voltage the luminance would range to minus infinity. The actual equations are, for the variation to power n

$$B = p(V + q)^n \tag{30}$$

where

$$\begin{aligned} q &= 1/\sqrt[n]{100} - 1; \\ p &= (1/100q^n); \end{aligned}$$

and for the exponential variation

$$B = 10^{2V}/100. \tag{31}$$

The bias, q, is not shown in the right plot of Fig. 17, but it must be included in the computation of the db signal range in the plot on the left. This shows the influence of the factor p.

For these characteristics the interference and differential sensitivities are plotted in Fig. 18. Comment on these is reserved until their application, as illustrated in Fig. 19, is discussed.

Examination of equations (27) and (29) shows that if the Fechner fraction, for some grade of impairment (such for example as threshold) for a given type of noise or modulation is known, the tolerance on noise-to-signal ratio (in decibels) is simply the difference between the Fechner fraction expressed in decilums and the interference or differential sensitivity. If the Weber-Fechner law holds in the region of interest, the Fechner fraction is a constant and the tolerance is merely that constant less the proper sensitivity.

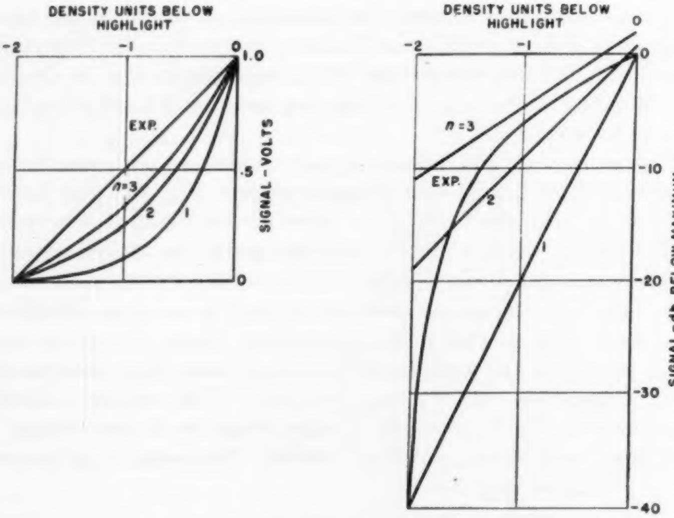


Fig. 17. Typical reproducer characteristics.

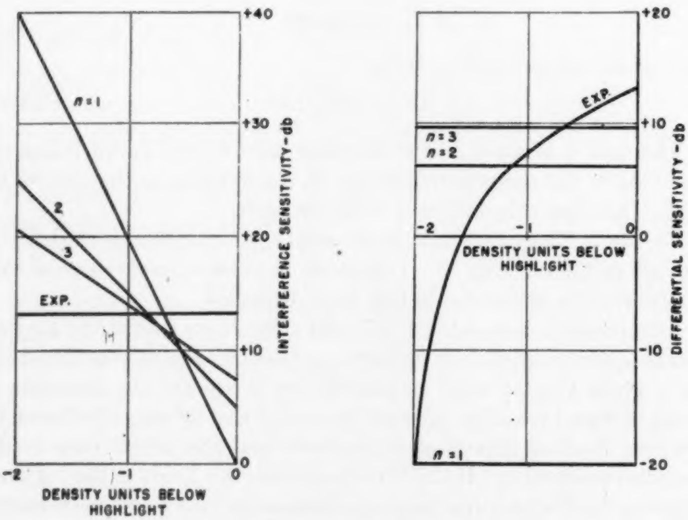


Fig. 18. Interference and differential sensitivities.

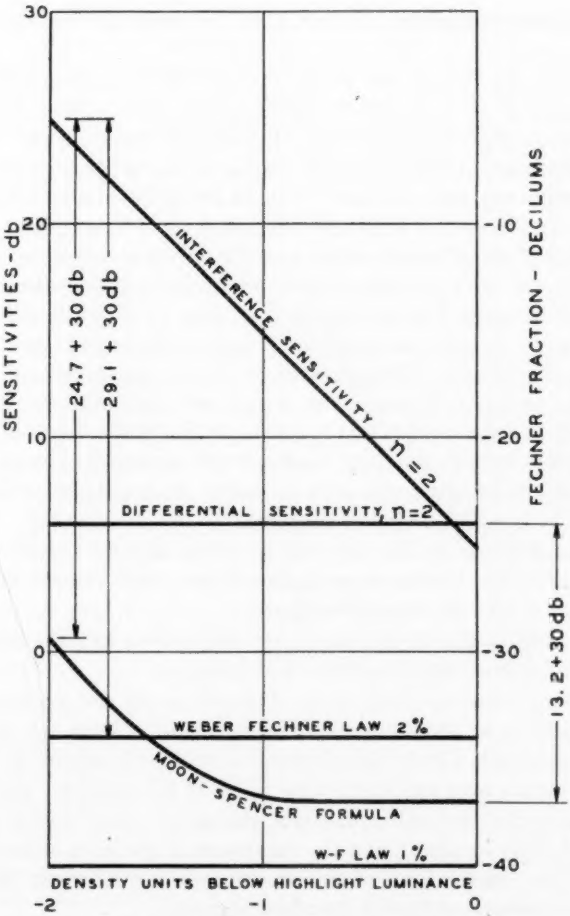


Fig. 19. Noise-to-signal requirements.

In Fig. 19 are plotted the Fechner fractions in decilums and the sensitivities (for $n = 2$) in decibels, over the picture luminance range which again is assumed as 100:1, or a photographic density range of 2. The scales on the Fechner fraction and sensitivities are offset 30 db, as shown, so that the curves may fall in approximately the same part of the plot. The Fechner fractions are shown at 2 per cent and 1 per

cent, assuming constancy in each case, following the Weber-Fechner law.

For such conditions, the additive noise will be visible only in the deep blacks ($b = -2$), and will have to be at 30 + 29.1 db = 59.1 db below the signal to be just visible with a Fechner fraction of 2 per cent. Modulation will be equally visible throughout the range of picture luminances, and will have to be at 30 + 10 = 40 db below the signal to be just visible with a Fechner fraction of 2 per cent.

Instead of the Weber-Fechner law the Moon and Spencer formula may be used, with the reservations which have already been noted. A plot is shown in Fig. 19, copied from Fig. 11 The parameter b of equation (16) is taken as equal to .01 and the highlight luminance B_S as 100 millilamberts. This gives $bB_S = 1$, and corresponds to a rather brightish picture. If the curve is assumed applicable to the noise threshold under consideration it indicates that while the noise will be most visible only in the deep blacks, it will be nearly as visible over about half the density range of the picture. At threshold the noise will be 30 + 24.7 = 54.7 db below the signal.

The modulation in this case will be about equally visible over the upper half of the density range of the picture, and at threshold will be 30 + 13.2 = 43.2 db below the signal.

With this illustration in mind it is now possible to make some general observations regarding Figs. 18 and 19.

1. With the assumption of the Weber-Fechner law, additive noise is generally most visible in the extreme blacks. With the exponential characteristic a limit characteristic is reached in which the noise is equally visible over the entire tone range of the picture. With deviations from the Weber-Fechner law, the noise susceptibility tends to be less sharply localized, and the maximum is apt to be shifted to the dark grays. In the limit of the exponential characteristic the maximum is broad and shifted to the white regions.

2. With the assumption of the Weber-Fechner law, modulation is generally equally visible over the entire tone range of the picture, although in the limiting exponential case the visibility is greatest in the extreme whites. With deviations from the Weber-Fechner law, modulation generally becomes visible over broad white regions or the extreme whites.

3. The characteristic for $n = 1$ gives, of those considered, the greatest susceptibility to additive noise, and the least to modulation.

4. As n is increased, the susceptibility to additive noise is reduced

while that to modulation is increased. The changes are slow beyond $n=2$. The two susceptibilities become approximately comparable in the limiting exponential case.

A diagram of the type of Fig. 19 is applicable for each case of the data of Figs. 5 and 8. Those particular data were taken with a flat field, hence each point corresponds roughly with the intersection of an appropriate Fechner fraction curve (either following the Weber-Fechner law or the Moon and Spencer formula) with the vertical axis at highlight luminance value. From the vertical distance to the appropriate picture tube characteristic it is possible to translate the ordinates of Figs. 5 and 8 to electrical signal to noise ratios for the near threshold condition. It is further necessary for setting tolerances on the noise, to determine the vertical distance between the two chosen curves, along the ordinate to the left of maximum highlight luminance corresponding to the maximum susceptibility to the noise.

The number and types of characteristics considered here are of course extremely limited. There are few receiving mechanisms that follow a pure law as assumed. In addition, negative modulation characteristics represent special problems. A more complete study of the subject should also include an examination of the point that, as the density range over which a given noise is rendered susceptible is increased, its general frequency of occurrence, and the geometrical area over which it is visible on any one picture, are both increased.

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An Improved Photomultiplier Tube Color Densitometer

By MONROE H. SWEET

Ansco, Binghamton, New York

Summary—**Previously, attempts were made to modify black-and-white densitometers to make them suitable for color measurements, but considerable difficulty was experienced with such modifications. Therefore, the Ansco Laboratories developed new electronic circuits utilizing the full capabilities of the photomultiplier tube for this purpose. These developments, combined with other refinements, have made it possible to design a densitometer capable of using sharp-cutting filters to measure color densities up to 4.0 and over.**

Introduction

Until quite recently, the photographic industry has been concerned mainly with black-and-white reproduction. This situation is reflected in the attention devoted to black-and-white sensitometry. However, during the past few years, the importance of color products has risen rapidly and in the case of motion picture film there are numerous commercial color processes now on the market and the number of production releases on color is growing continuously. As a result of this trend there is a corresponding demand for appropriate testing and control instruments and techniques.

One important aspect of three-layer color-film sensitometry is the measurement of color densities of the processed test strips. In sharp contrast to black-and-white densitometry, wherein it is permissible to use the entire radiation from a given light source to excite the phototube receiver, in color densitometry it is desirable to make density measurements of the materials using narrow spectral-energy bands, preferably at single wavelengths. This requirement rules out the possibility of using relatively simple receiving systems of limited sensitivity or relatively inefficient optical systems—a luxury available only in black-and-white densitometery. When one confines the radiation to a desirably narrow band, he is confronted with a reduction of the available energy by a factor of 100 to 1000 or more before absorption by the specimen itself is even considered. Therefore,

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relatively drastic changes are necessary in the design of instruments which are required to do an equally good job in color as had previously been done in black and white.

EARLY COLOR DENSITOMETERS

In order to meet the problem of color densitometry, Evans proposed the use of a cleverly modified visual densitometer and reported it to this group.[1] Later, null techniques incorporating high-gain amplifiers of special design were used in some objective instruments to achieve the necessary sensitivity. Instruments of this type were too slow to use for routine work although they were satisfactory for some applications where the volume of work was relatively small. In order to overcome their disadvantages, at Ansco a direct reading black-and-white densitometer was modified in such a way as to provide the necessary high sensitivity and yet preserve its other major features.[2]

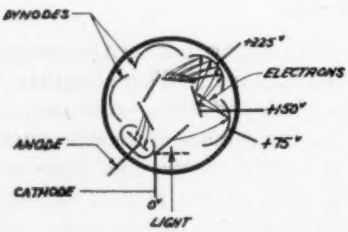

Fig. 1—Explanatory diagram of electron-multiplier-tube operation.

In this instrument an electron-multiplier type of phototube was substituted for the simple phototube used in the original. This new tube operates according to the principles shown in Fig. 1. For each electron emitted by the action of light on the cathode, on the average two or more electrons are emitted by secondary emission from each succeeding dynode element. Therefore, the input current is amplified many times when it reaches the anode. The use of the photomultiplier tube increased the sensitivity of the original instrument by a factor of 10,000 but it was necessary to take special precautions to shield and insulate the entire multiplier-tube supply and the multiplier tube itself because of unfavorable polarity relationships. In spite of a consequent tendency toward instability the instrument was put into routine use and it quickly demonstrated the value of a simple direct-reading densitometer in color development and color-control work.

In the course of further development work, a photomultiplier-tube circuit was devised which retained the high sensitivity of the modified instrument described above and in which the inherent stability was greatly improved. A compensating circuit was also developed which enables the user to calibrate the scale of the instrument to agree closely with virtually any desired reference standard.

MULTIPLIER-TUBE FEEDBACK DENSITOMETER

Photomultiplier tubes have acquired a reputation in some circles for instability. This is because many mutliplier tubes, when operated at a constant dynode voltage, show pronounced fatigue at even moderate light levels.[3] If one attempts to cover a density range of 0 to 3 by conventional use of the photomultiplier tube he often encounters fatigue at the high light levels (low densities) and dark current at the lowest light levels (high densities). It is known that the fatigue effects are most serious in the last few dynode stages and occur whenever the current is of large magnitude and changes appreciably. *In the present case the anode is operated at a constant-current level and the last few dynodes are operated at comparatively constant currents regardless of the densities being measured.* Therefore, the stability of the circuit is comparable to that of a multiplier tube operated in conventional circuits, but maintained under ideal optical and electrical conditions; namely, at constant dynode voltage and with a constant level of incident flux.

Furthermore, when operated in conventional circuits, photomultiplier tubes require a precision-stabilized high-voltage source. The present circuit completely avoids the necessity for such a source.

BASIC CIRCUIT*

The basic operating principles of the photomultiplier-tube circuit can best be demonstrated by reference to Fig. 2. In this illustrative circuit the operator manually adjusts the voltage applied to the multiplier dynodes in such a way as to keep the multiplier-tube output current constant at all light levels. When a given specimen density is inserted in the light beam, the multiplier-tube output current is at first reduced but is then restored to its original value by increasing the dynode voltage. A voltmeter which responds to the dynode voltage applied to the tube can be calibrated in terms of density and

* Protected by United States Patents 2,478,163 and 2,457,747. Patents on other novel features are pending.

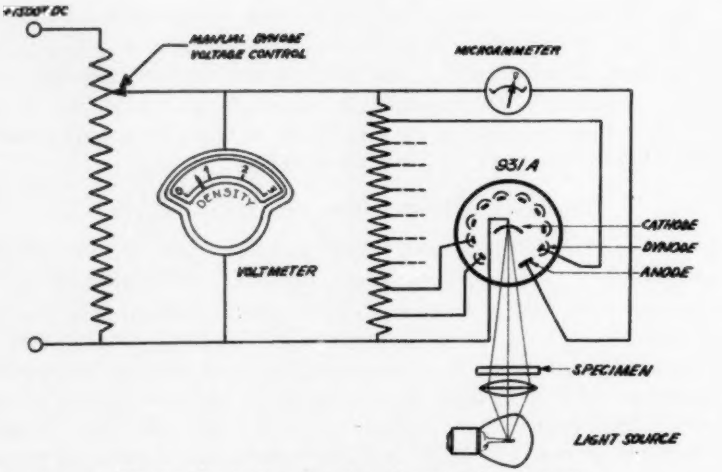

Fig. 2—Illustrative dynode-voltage-feedback circuit.

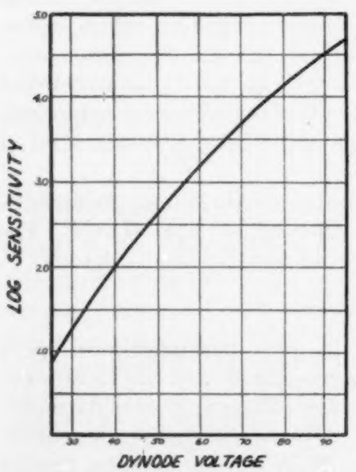

Fig. 3—Relationship between dynode voltage and log (sensitivity) for a typical photomultiplier tube.

the scale will be fairly uniform since the relationship between phototube sensitivity and dynode voltage is virtually logarithmic† as shown in Fig. 3. In actual practice an electronic tube performs the dynode voltage adjustment automatically and instantaneously. Therefore, in effect the sensitivity of the multiplier tube is continuously adjusted so that when the light intensity is high the gain of the tube is low and vice versa. The product of light intensity and tube sensitivity is at all times constant.

Fig. 4 is a simplified schematic diagram of the densitometer circuit. The voltage applied to the 931-A photomultiplier-tube dynodes is derived from the drop across

† Density, $D = \log_{10}(1/F) = \log_{10}(O)$. In which unit flux is incident on the specimen, F is the flux transmitted, and O is the opacity of the specimen.

the cathode resistor R of the type 807 control tube. This voltage is controlled by the grid G whose potential is determined by the anode current of the photomultiplier tube (by virtue of the voltage drop it creates across the grid resistor R').

The electrical-polarity relationships are such that, as illustrated, an increase in illumination on the phototube causes the voltage across R to drop and therefore the effective sensitivity of the 931-A tube to decrease. This negative-feedback action is continuous and therefore the voltage developed across R is a reliable measure of the phototube

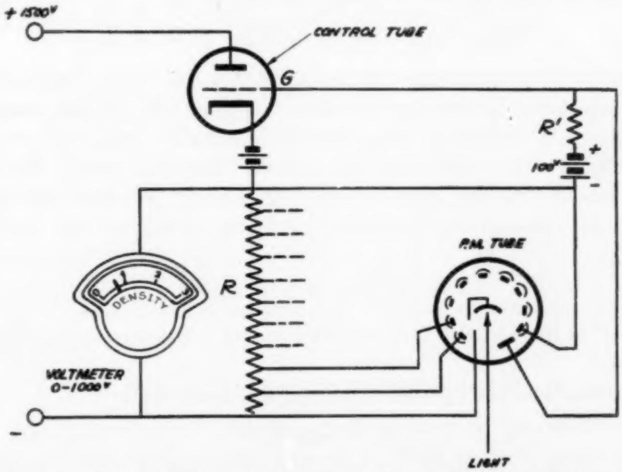

Fig. 4—Simplified schematic diagram of multiplier-tube feedback densitometer.

illumination. A few of the specific advantages obtained from the use of this circuit are: 1. High sensitivity with high stability. 2. An approximately logarithmic electrical response over a wide range of light levels. 3. Reduction of photomultiplier-response fatigue. 4. Elimination of the need for a stabilized high-voltage power supply.

THEORY OF OPERATION

Dynode Voltage Versus Density Relationship

From the qualitative description of the instrument given above it will be recognized that the uncompensated output of the instrument

portrays the relationship between dynode voltage and photomultiplier-tube sensitivity. The equation,

$$S = k \cdot E^{n/2} \tag{1}$$

where S = net sensitivity of tube in terms of anode current per unit incident radiant flux
k = a constant, characteristic of the tube
E = dynode voltage
n = number of stages

is often used to express this function* but it is not immediately apparent that E versus S is even quasi logarithmic,

$$\text{since} \quad \log_{10} S = (n/2) \log_{10} E + \log k.$$

However, the following treatment shows that when $n/2$ is large, the relationship between E and $\log S$ approaches linearity over the finite range of operating values of S encountered in practice.

In the present discussion it is assumed that the anode current is held constant in the presence of variations in incident flux on the photomultiplier tube by control of the dynode voltage.

Thus

$$F \cdot S = K \text{ or } S = K/F \tag{2}$$

where F is the radiant flux received by the photosurface and K is a constant.

By definition, the optical density of the specimen is

$$D = \log_{10} (1/F)$$

where unit flux is incident on the specimen and F represents the transmitted flux received by the phototube and from (2) in the present circuit

$$\log S = \log K + (\log (1/F) = D)$$

from (1)

$$\log S = \log k + n/2 \log E$$

$\therefore$

$$D = n/2 \log E + K' \tag{4}$$

where

$$K' = \log k - \log K$$

* C. C. Larson and H. Salinger, "photo-cell multiplier tubes," *Rev. Sci. Instr.*, vol. 11, pp. 227; July, 1940. The fundamental photomultiplier tube equation is $S = k \times G^n$, in which G is the gain per stage.

and

$$dD/dE = (n/2)\ (\log_{10} e)\ (1/E). \tag{5}$$

The ratio of the slope (dD/dE) taken at a specimen density of 2.0 to that taken at density 0.0 is a convenient measure of the "linearity" of the system. Letting M represent this ratio,

$$M = \frac{(dD/dE)_{D=2.0}}{(dD/dE)_{D=0.0}};\ \text{from (1)} \quad E = (k/S)^{-2/n}$$

therefore $$M = \frac{[(n/2)(\log_{10} e)(k/S)^{2/n}]_{2.0}}{[(n/2)(\log_{10} e)(k/S)_{0.0}]^{2/n}} = \left(\frac{S_{0.0}}{S_{2.0}}\right)^{2/n} \tag{6}$$

which shows that as the number of dynode stages n *increases,* M *approaches unity as a limit and the voltage is linear with density.*

In the 931-A tube $2/n \cong 0.23$ and if $D_0 = 0$ and $D_2 = 2.0$, $(S_0/S_2) = 1/100$. Under these circumstances $M = 0.36$, whereas for a conventional circuit operated at constant dynode voltage $M = 0.01$ for the same density range.

The compensating circuit described in a subsequent section provides the correction necessary to maintain a constant slope of the dynode voltage versus density curve over the operating range of the densitometer.

FEEDBACK-AMPLIFIER PERFORMANCE

It was stated earlier that the performance of the instrument is unaffected by ordinary variations in the high-voltage power supply. This fact will become evident from the following proof of independence of the instrument's performance with respect to changes in the amplifying characteristics of the control tube.

In Fig. 5* the photomultiplier tube is shown as P. E represents the voltage developed across the dynode resistors of resistance R. I is the 807 control tube plate-cathode current. E_b is the voltage developed across the gaseous stabilizer tube of the actual circuit and is here represented as a battery to provide a suitable operating potential between the photomultiplier-tube anode and dynode No. 9. E_c is the voltage applied to the photomultiplier-tube load resistor r and is referred to ground. The photomultiplier anode current is

* In the actual circuit, a cathode-follower tube is inserted between point X and the 807 grid but it has no significant effect on the analytic behavior of the basic circuit treated here.

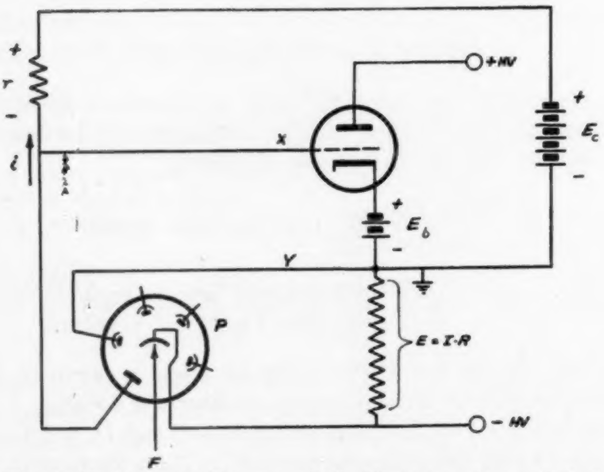

Fig. 5—Explanatory diagram which illustrates the analytical behavior of the dynode-voltage-feedback circuit.

i and F is the flux incident on the photo cathode. As drawn, the following relationships apply:

$$\begin{bmatrix} E_g = E_{xy} - E_b \\ E_{xy} = E_c - i \cdot r \\ E_g = E_c - E_b - i \cdot r = E_a - i \cdot r < 0 \end{bmatrix} \tag{7}$$

where

$$E_a = E_c - E_b.$$

Since the sensitivity, S, of the photomultiplier tube may be defined as

$$S = i/F, \text{ then (from (1)) } i = F \cdot k \cdot E^{n/2}$$

and

$$E = I \cdot R = (g_m \cdot E_g) \cdot R \tag{2}$$

where

$$g_m = \left(\frac{\partial I}{\partial Eg}\right)$$

then

$$E = g_m \cdot R[E_a - F \cdot k \cdot r \cdot E^{n/2}] \tag{8}$$

and

$$\partial E/\partial F = [-k \cdot r \cdot E^{n/2} - (n/2) \cdot F \cdot k \cdot r \cdot E^{(n/2)-1} \partial E/\partial F] g_m \cdot R$$

$$= \frac{-g_m \cdot R \cdot k \cdot r \cdot E^{n/2}}{1 + n/2 \cdot F \cdot k \cdot r \cdot E^{n/2-1} \cdot g_m \cdot R}$$

$$= \frac{-k \cdot r \cdot E^{n/2}}{(1/R \cdot g_m) + n/2 \cdot F \cdot k \cdot r \cdot E^{n/2-1}}. \tag{9}$$

Equation (9) shows that if $(R \cdot g_m)$ is large, the relationship between E and F will be independent of R and g_m. Furthermore, since variations in the high-voltage supply to the 807 control tube can effect the circuit only by changing the effective value of g_m, the present circuit likewise is independent of fluctuations in the 807 plate-supply voltage.

Compensating Circuit

As mentioned in the introduction, a convenient optical system of arbitrary geometry and relatively high efficiency was adopted but the resulting density values obtained, particularly with scattering specimens, do not perfectly conform with those obtained according to techniques prescribed by the American Standards Association for the determination of Diffuse Density.[4] For this reason alone it would be desirable to provide some automatic scale compensating feature. In addition, the fact that the relationship between E and (log F) is not quite linear in the case of the 931-A makes such a feature even more desirable since it can be used to correct both distortions simultaneously.

Therefore, a circuit was developed which corrects the output voltage in such a way as to give a close approximation to the desired calibration ($\pm$ 0.02 over the density range 0.0 to 3.0). Its basis of operation is illustrated in Fig. 6.

The output meter 0 measures the total dynode voltage AB with the indicated electrical polarity so that Z is always negative with respect to A and the magnitude of the voltage E_{AZ} is of course directly proportional to the current flowing through R_2.

Now if there were no compensation, the family of possible specimen-density versus meter-reading curves which could be obtained by control of shunt S is shown in Fig. 7, where curve A represents the lowest shunt resistance and curve F the highest. The heavy straight line represents the ideal relation. It will be noted that curve E gives reasonable agreement with the ideal values over the density range 0 to 0.5.

If it were possible in the case of curve E to readjust continuously

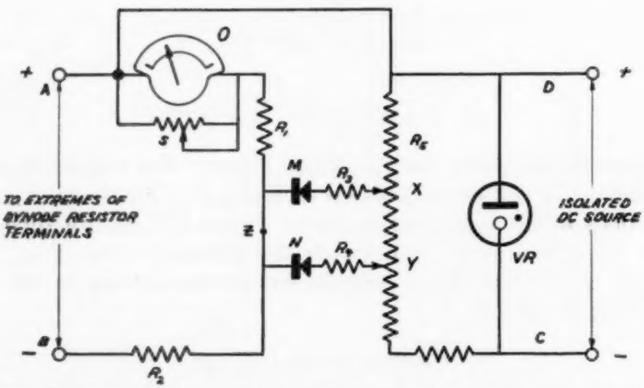

Fig. 6—Circuit which provides corrective action resulting in a uniform relation between specimen density and meter current.

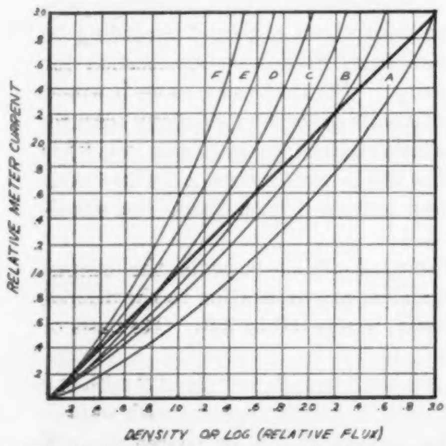

Fig. 7—Family of specimen-density versus meter-current curves obtained by varying shunt resistor S of Fig. 6.

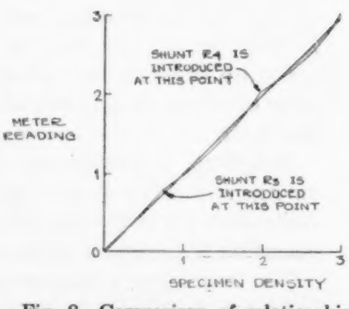

Fig. 8—Comparison of relationship between specimen density and resulting meter current after compensation. (Errors exaggerated for illustrative purposes.)

the shunt S to a lower resistance value at all points corresponding to density 0.5 and above, it is clear that the approach to the ideal relation could be extended over a wider density range.

This is done, in effect, by the action of the compensating circuit shown in Fig. 6. Voltage E_{AZ} rises continuously with increasing density. Voltage V_{CD} is stabilized by the voltage-regulator tube and resistor R_5 is a relatively low impedance unit. If the variable tap

of R_3 is so adjusted that voltage E_{AZ} = voltage E_{AX} when the specimen density is 1.0 then at all higher densities (and therefore higher E_{AZ} voltages) rectifier M will pass current because the voltage difference E_{XZ} will be of proper polarity for conduction. Furthermore, if rectifier M is of low resistance it may be regarded as a switch which closes whenever voltage E_{AZ} exceeds E_{AX} and opens when E_{AZ} is less than E_{AX}. Under these conditions whenever the specimen density rises above 1.0, R_3 will act as a shunt path for the meter and if its value is properly selected a curve of the type shown in Fig. 8 between 0 and 2 will result. The range of satisfactory calibration may thereby be extended to cover the range 0–2. The correction is automatic, reliable, and instantaneous.

By adjusting the variable tap of R_4 so that voltage $E_{AZ} = E_{AY}$ when the specimen density is 2 the correction can be extended up to density 3. The number of corrective steps that *could* be used obviously is unlimited. However, two such shunts perform the correction satisfactorily.

Thus the compensating circuit provides an output current that is linear with density, making the instrument uniquely suited for automatic linear density recording by connecting the output to any standard ink recording milliammeter.

The circuit used in the actual instrument incorporates two independent sets of compensating circuit elements. One set is used when reading the densities of ordinary silver images and is adjusted at the factory so as to give results which are in approximate agreement with those obtained by ASA Diffuse-Printing-Density Type P-2b.* The second set is adjusted so as to give results which are in agreement with those obtained by a proposal submitted to the ASA for color densitometry.† A switch located on the right-hand side of the case permits

* In spite of the fact that the geometry of the optical system does not conform with that under which primary diffuse printing density measurements of the American Standards Association are made, the agreement has been shown to be sufficiently good for samples of widely different grain size as to permit the small errors to be ignored in routine sensitometric work. Specific data concerning the differences resulting from the use of an instrument incorporating a similar optical system have been reported earlier.[5]

† The order of the agreement obtained in this way is considered satisfactory for routine photographic sensitometry. Departures from the ideal values are kept at a minimum by virtue of the fact that the dyes used in most commercial processes are not sufficiently sharp cutting to cause serious errors in the results in the present case where the spectral purity of the source-filter-receiver combination is relatively high.

the selection of either circuit. The principal reason which necessitates using two circuits is the difference in diffusion between the silver and color film specimens; i.e., silver images have a relatively high scattering power whereas ordinary color-film samples scatter little light and the corresponding differences in effective density versus standard density require different degrees of compensation. Either one or both sets of controls can be readjusted, in a matter of minutes, to bring a given instrument into agreement with values obtained by the use of some other standard.

In its commercial form the bias points X and Y are both adjustable by potentiometers as are also resistors R_3 and R_4. This involves eight controls in all, which are accessible through a door on the right-hand side of the instrument case.

When used as a photometer for measuring external light levels or as a reflection densitometer, it is desirable to have the meter respond uniformly to uniform changes in log (incident flux). This requirement is well satisfied when the compensating circuit switch is placed in the "color" position.

FATIGUE REDUCTION

"Fatigue" is an undesirable characteristic of many electronic processes. As an example, when one irradiates a barrier-layer photocell with bright light the initial output current may be relatively high, but the response usually will fall off (exponentially) with time until eventually it reaches a stable value.

In the case of the electron-multiplier phototube similar effects may be found which are attributable to the fatigue of the secondary emissive dynodes. Although the photosurface itself may contribute to the over-all fatigue effect too, this is not the usual case in photomultiplier-tube operation because the level of incident radiant energy is very low.

Qualitivatively, the benefits of the feedback circuit, as a means for reducing fatigue, may be appreciated by the following argument:

1. In practice, virtually any electronic device such as a multiplier tube will provide a stable output after a given time if all pertinent operating conditions are held constant. In the present case if the dynode voltage is stabilized and the incident flux on the photosurface is held constant, after a certain period the anode-current output will reach an equilibrium value.

2. Fatigue effects (which in photomultiplier tubes are confined to

the dynodes) will be some function of recent changes in electron bombardment of each of the dynodes involved. This is of course equivalent to a statement that the yield in secondary-emission ratio depends on the immediate history of the incident bombardment current on the dynode surface. It can therefore be appreciated that the magnitude of the fatigue in any specific case is a function of the magnitude of the disturbance from previous equilibrium conditions.

3. In the conventional or constant dynode voltage operation each dynode experiences major changes in bombardment current which are directly proportional to the changes in the flux level incident on a phototube. In the case of inverse-feedback operation the change in initial bombardment current for any given dynode, for an identical change in incident radiation on the photosurface, is less than in the constant dynode voltage operation case because the dynode voltage is always simultaneously changed in such a direction as to tend to maintain the dynode currents constant.

4. If now, we plot, for the inverse-feedback operation case a curve which relates dynode voltage to incident flux and consider any particular point on the curve, an arbitrary displacement along the curve will correspond to a specific change in flux level and a specific change in dynode voltage. Or conversely, if as the result of fatigue effects the tube sensitivity is reduced to a fixed amount, the change in dynode voltage necessary to restore the original output can be determined readily. Therefore, it is convenient to think of the changes in voltage in the inverse-feedback operation case in terms of the equivalent changes in incident optical flux.

5. Since in every case where comparable conditions of incident flux exist inverse-feedback operation will result in smaller corresponding changes in dynode bombardment current than in the constant dynode voltage operation case, the consequent fatigue effects, (as measured in terms of the increase in flux level necessary to restore the initial anode current in the case of constant dynode voltage operation and the initial dynode voltage in the case of inverse-feedback operation), will also be less.

The above analysis demonstrates the superiority of inverse-feedback operation qualitatively. In the following quantitative analysis, it will be shown mathematically that the difference between dynode bombardment currents in the case of constant dynode voltage operation and inverse-feedback operation is negligible for the first five or six stages but that in subsequent stages the difference becomes

significant. It is assumed throughout this discussion that in the case of inverse-feedback the amplification of the control tube is infinite and therefore that the photomultiplier-tube output current is constant regardless of the incident-flux level.

The analytical expressions for the anode current, as a function of fatigue, are as follows:

For either constant dynode voltage or inverse-feedback operation

$$
\begin{aligned}
I_t &= I_{P.C.} \cdot [G_1' \cdot G_2' \ldots G_9'] \\
&= I_{P.C.} \{G[1 - k \cdot q_{P.C.}(1 - a^{-t})] \cdot G[1 - k \cdot q_1(1 - a^{-t})] \ldots G \\
&\qquad [1 - kq_8(1 - a^{-t})]\} \\
&= I_{P.C.} \, [G(2 - \beta_1) \cdot G(1 - \beta_2) \ldots G(1 - \beta_8)]
\end{aligned}
$$

I_t = anode current at time t

$I_{P.C.}$ = photosurface current produced by incident flux

$G_1', G_2' \ldots G_9'$ = gain of each dynode after elapsed time t

G = gain per stage before onset of fatigue and is assumed to be the same, initially, for all dynodes

β = "fatigue factor" and in this case is chosen equal to $k \cdot q \cdot (1 - a^{-t})$ where

k = a constant which determines the upper limit (G_n') to which dynode stage n will fatigue when $t = \infty$

q = a function of the current bombarding the particular dynode in question and therefore depends on the product of the preceding terms of the equation.
In this case it is chosen as equal to Δi_n where i_n represents the bombarding current for the nth dynode.

a = a constant which determines the rate of fatigue with time

t = the time elapsed since the onset of fatigue

The ratio of the initial to final outputs is

$$
\begin{aligned}
R = \frac{I_\infty}{I_0} &= \frac{I_{P.C.} \cdot G^2(1 - kq_1) \cdot G(1 - kq_2) \ldots G(1 - kq_8)}{I_{P.C.} \cdot G^9} \\
&= (1 - kq_1)(1 - kq_2) \ldots (1 - kq_8).
\end{aligned}
$$

Let R' be a measure of the decrease in fatigue and equal

$$
\frac{R_{CDO}}{R_{IFO}} = \frac{[(1 - kq_1)(1 - kq_2) \ldots (1 - kq_8)]_{CDO}}{[(1 - kq_1)(1 - kq_2) \ldots (1 - kq_9)]_{IFO}},
$$

where R_{CDO} = the ratio R, above, for the case of constant dynode voltage operation and R_{IFO} is for the inverse feedback case.

Now if $k = 0.1$ and β is taken as $[0.1(\Delta i/i)(1 - a^{-t})]^*$ and a change of illumination of 1:1000 is considered, then

$$
R' = \frac{(1 - 0.1)^9}{(1 - 0.1)^6(0.91)(0.92)(0.95)} = 0.88.
$$

The treatment is considerably simplified if we allow the time t to approach infinity and confine our attention to initial and final values of output which result from a given change in flux level. It is also convenient to ignore the small change in β which takes place as a consequence of the slight reduction in actual bombardment currents during the fatigue process itself. With these simplifications, for a change in incident light of 1:1000, in the constant dynode voltage operation case the output will fatigue to 0.37 of its initial value whereas in the inverse-feedback operation case the output will fatigue to only 0.43 of its initial value. Therefore, operation of the tube in an inverse-feedback circuit represents a definite improvement with respect to fatigue of 1:0.88. It should be noted that in the treatment of the inverse-feedback operation, the anode current output is investigated as though no feedback were present, once the total level of the incident flux has changed to its new level and the general magnitude of the corresponding dynode-amplification factors have been established.

From the above discussions it is clear that feedback operation presents a real advantage from the standpoint of fatigue at all light levels although its advantage in this respect is greatest when extremely large differences in operating flux levels are involved.

CIRCUIT DETAILS

Fig. 9 shows the actual circuit. The high-voltage power supply for the multiplier tube is conventional but it is not stabilized since the associated control circuit automatically compensates for line-voltage fluctuation. A Type 807 beam-power pentode serves as the control tube for the dynode voltage. Its plate-cathode circuit includes the dynode-voltage dropping resistors which divide the total dynode voltage into equal increments for distribution to the individual dynodes. A 12SF5 triode is inserted between the photomultiplier-tube anode circuit and the 807 control grid and acts as a cathode follower. The operating conditions of the 12SF5 are such that its grid current is at all times less than 10^{-8} ampere yet its output impedance is low enough that the development of slight grid current during the life of the 807 control tube will not disturb the performance of the instrument as a whole.

* Results obtained for R' with this value of β are very nearly the same as those obtained with $\beta = k\,(\Delta i)(1 - a^{-t})$ and $\beta = k(i\Delta i)(1 - a^{-t})$ since the β values for the first 6 stages are nearly identical. The electron bombardment of the first dynode stage *is* identical for both inverse-feedback and constant dynode voltage operation at equal light levels.

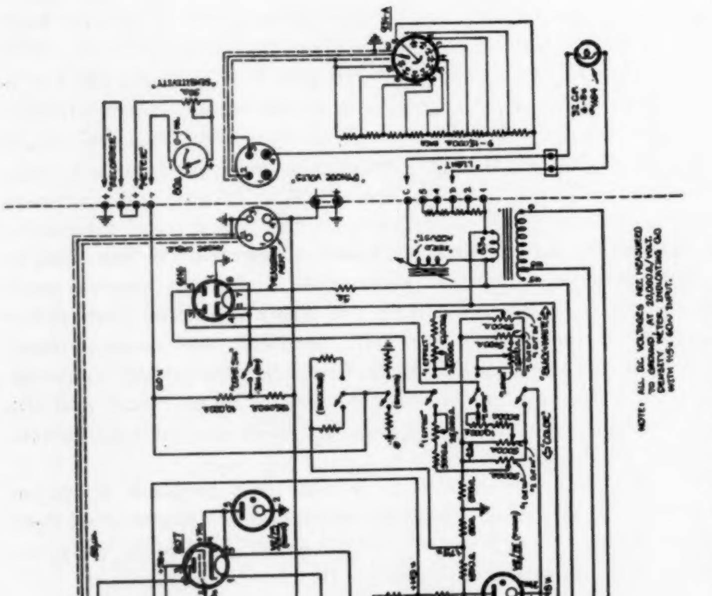

Fig. 9—Wiring diagram of Ansco Color densitometer Model 12.

Experience shows it is desirable to operate the multiplier tube with a constant dynode No. 9-to-anode voltage of between 50 and 80 volts. A constant-voltage gas tube, inserted between the 807 cathode and dynode No. 9 terminal, performs this function satisfactorily. Over the entire operating range of the device the voltage swing of the photomultiplier tube anode-to-807 cathode is less than 5 volts. Since the 807 cathode-dynode No. 9 voltage is sensibly constant the photomultiplier tube anode-to-dynode No. 9 voltage swing is only slightly more than 5 volts.

If the voltage applied to the photomultiplier anode load resistor is sufficiently high the anode current will automatically be held nearly constant throughout the operating range of the instrument. The voltage actually applied is more than 100 volts and therefore the variation in anode current is of the order of only 5 per cent.

It is necessary to provide a "bucking current" to counteract the current developed in the dynode-voltage-measuring circuit when there is maximum incident flux or zero specimen density (minimum dynode voltage). This is conveniently obtained from the stabilized 807 screen-voltage supply. The bucking current is approximately 2 milliamperes and the normal range of applied dynode voltage is 30 to 90 volts per stage.

The theory of the compensating circuit has already been discussed. A type 6H6 twin-diode vacuum rectifier serves its purpose in this circuit very well since it has relatively low forward resistance and passes negligible reverse current. All resistors except the photomultiplier anode load resistor are wire-wound.

To provide power for various attachments, stabilized low voltage is accessible through a door located at binding posts at the rear of the instrument.

Depending upon the sensitivity of the individual instrument, the lamp is connected to its source through different taps of a resistor. In all cases, stepless control of lamp brightness is affected by operation of a gear-driven solenoid which serves as a "zero" control. The output meter is a standard Weston Model 273 fan-shaped milliammeter having a long scale and high speed of response.

The basic instrument is believed to provide the highest sensitivity of any general purpose commercial photometer,* and there are many desirable ways in which this feature can be used. In the present case,

* The average Model 12 densitometer reads full scale (density 3.0) with an excitation of only 0.1 microlumen of energy 2870 degrees Kelvin.

this sensitivity is used principally to incorporate sharp cutting, but very dense, gelatin-foil filters in the path of the light beam in order to obtain high spectral purity without resort to monochromators, interference filters, gaseous discharge sources, or the like.

OPTICAL SYSTEM

With reference to Fig. 10, light from a 6-volt concentrated filament automobile lamp, controlled as indicated in the preceding section, is collimated by an aspheric lens after passing through a glass infrared absorbing filter. The beam then passes through a liquid cupric chloride filter which absorbs the radiation of wavelengths greater than 645 millimicrons but transmits virtually all of the shorter wavelength radiation. A second condenser focuses the beam on a 3-mm diameter aperture mounted in the top plate of the instrument proper. After partial absorption by the specimen the light is further absorbed by the "color filter" and is finally intercepted by the photomultiplier-tube cathode surface. The "color filter" actually consists of a pack of several small gelatin-foil filters which serve to confine the continuous spectrum of energy emitted from the tungsten source to each of the desired wavelengths. There are six sets of filters, each set being located over a different aperture in a "filter cylinder" surrounding the phototube.

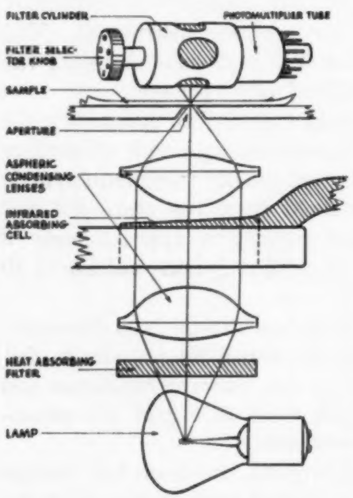

Fig. 10—Optical system of Ansco Color densitometer.

In one position a red-filter pack is used which serves to absorb radiation of wavelengths shorter than 644 millimicrons. In this case, the cupric chloride filter serves as the long-wave absorber with the result that the radiation reaching the photosurface is nearly pure spectral energy of 644 millimicrons wavelength.

In another position the filter pack is such as to confine the transmitted radiation to spectral energy of wavelength 546 millimicrons. Similarly in a third position the transmitted wavelength is 436 millimicrons.

In the fourth position a "Visual" filter is interposed. This filter is of such design as to reproduce the response of the eye when taken in combination with the spectral characteristics of the cupric chloride liquid filter, and the spectral sensitivity of the photomultiplier tube.

A fifth filter position labeled "3" interposes enough neutral density that the flux received by the phototube comes within the range of operation of the instrument in view of the finite range of adjustment of the lamp-intensity control. This permits black-and-white densities from 0 to 3 to be measured directly. The sixth filter position, labeled 6, uncovers the phototube completely and in this case when a specimen density of 3.0 is placed in the sample position the meter reading can be brought to zero thereby permitting black-and-white densities from 3 to 6 to be measured. Ordinarily, there is sufficient latitude of flux control to permit measurement of densities up to 7.5.

The spectral characteristics of the combined source-phototube-filter-receiver products for the different filter cylinder positions of recent production units are illustrated in Figs. 11 and 12. It is believed that the visual filter combination shown in Fig. 12 represents one of the best approximations to the response of the eye yet obtained with a phototube having a spectral response similar to the average *S-4* surface

Although at the present time there is no standard for color densitometry (either ASA or SMPE) nor even a recommended practice, a proposal has been made to the American Standards Association for their consideration for adoption as an American Standard. This proposal specifies that for the densitometry of three-layer monopack color film the measurements shall be made at the three wavelengths corresponding to the prominent mercury and cadmium lines of emission which fall at 436, 546, and 644 millimicrons. These wavelengths lie close to the spectral density peaks of the average commercial color film. Furthermore, there is a good reason to believe that any satisfactory three-color process would of necessity have absorption peaks falling close to those specified. Therefore, it was a design goal to provide narrow band isolation filters which coincided in peak transmission with the proposed standard.

In Figures 11 and 12 the maximum log reciprocal (relative response) for each of the three blue, green, and red filters has been adjusted to zero. Actually, the *minimum* filter density, in the case of the blue filter, is approximately 4.0 at 436 millimicrons and since this

is virtually monochromatic, less than 1 part of 10,000,000 of the total energy of the initial beam is ultimately received by the phototube. It is somewhat difficult to design a satisfactory red-filter combination in spite of the greater relative energy emission of the tungsten lamp,

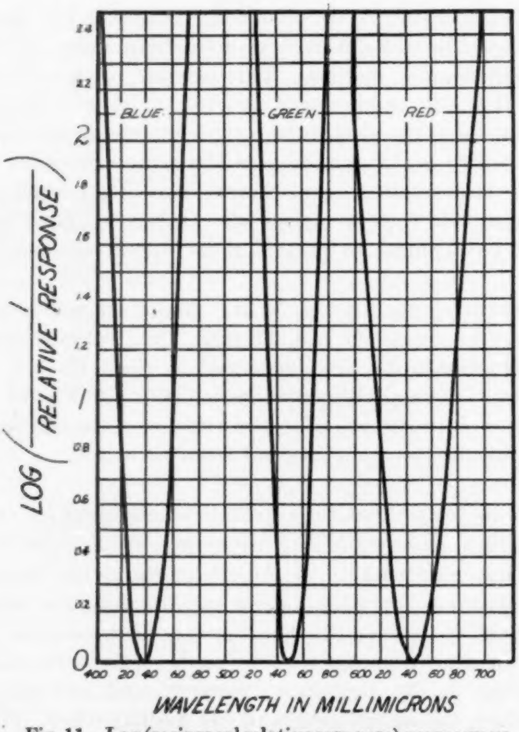

Fig. 11—Log (reciprocal relative response) versus wavelength for the three-color filters used for transmission measurements in the Ansco Color densitometer. The wavelengths corresponding to peak transmission coincide with those of a proposal made to ASA for color densitometry.

because the phototube response is relatively very feeble at wavelengths greater than 600 millimicrons. Although somewhat broader in its transmission band than the rest, the red-filter combination is sufficiently narrow for most practical sensitometric purposes.

The spectral characteristics of the combined system, when the filter control is put in the "3" and "6" positions are such as to meet the

requirements for measuring American Standard Density Type P-2b It is a simple matter to remove the cover plate of the measuring arm and substitute other gelatin filters for those originally provided, should this be desired.

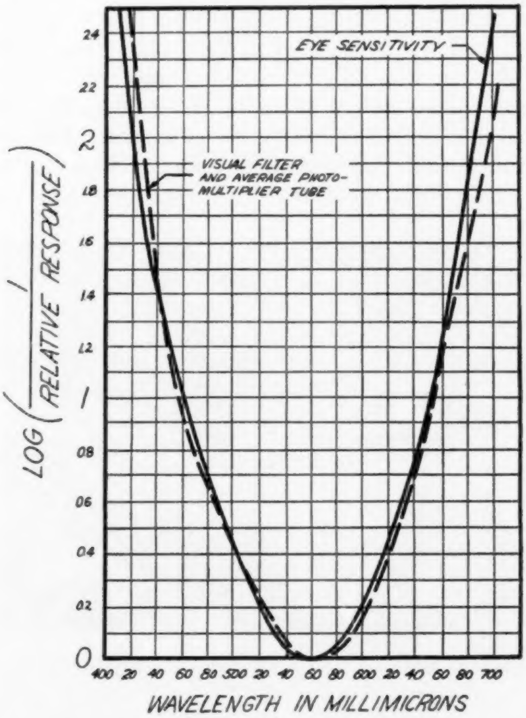

Fig. 12—Log (relative response) versus wavelength for the "visual" filter used in the Ansco Color densitometer, shown in comparison with the response curve of the eye.

The lamp voltage is controlled by a variable solenoid inductance and provides the required latitude of flux density. The arrangement permits smooth lamp operation of practically unlimited life.

APPLICATION AND PERFORMANCE

Fig. 13 is a photograph of the complete instrument. In use, the operator turns the instrument on with the rotary switch located at

the left of the measuring arm and after allowing a few minutes for the initial warm-up makes the zero adjustment with the filter selector and compensating circuit controls in their appropriate positions. The sensitivity control, located at the right of the measuring arm, is then adjusted so that a calibrated reference-density specimen gives a reading in agreement with its assigned value. The instrument may then be used for the corresponding position of the "Color—Black-and-White" switch, it being only necessary to check the zero and sensitivity-control adjustment occasionally during warm-up. It is recommended that in cases where the instrument is used daily, it be left in continuous operation. This minimizes the frequency at which zero and sensitivity checks are necessary. Since all of the components

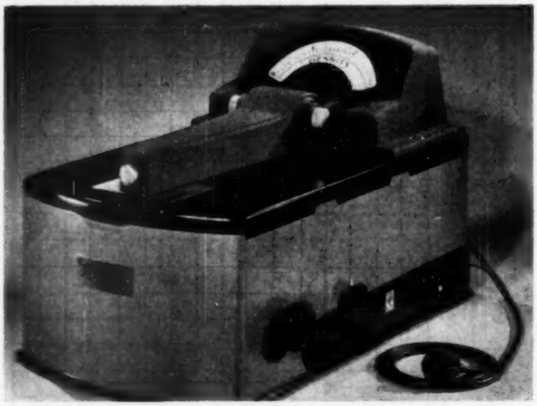

Fig. 13—External view of the Ansco Color densitometer.

are operated at well below their nominal capacity, they have a long useful life.

For reading color densities, with the "Color—Black-and-White" selector switch in the "Color" position, the operator simply adjusts the sensitivity to give a meter reading which is in agreement with the preassigned reference density value using the green filter, then proceeds to take routine readings. In the case of black-and-white measurements a similar check reading is made with the selector set switch in the "black-and-white" position and with the filter selector at "3" densities between 0.0 and 3.0 are then read directly. Densities between 3.0 and 6.0 may be read by inserting sufficient sample den-

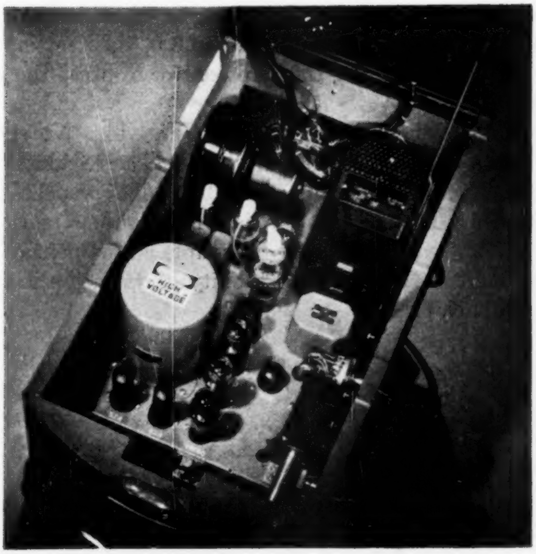

Fig. 14—Instrument chassis—showing high-voltage transformer, control and rectifier tubes, lamp-voltage stabilizer, and zero-adjustment solenoid.

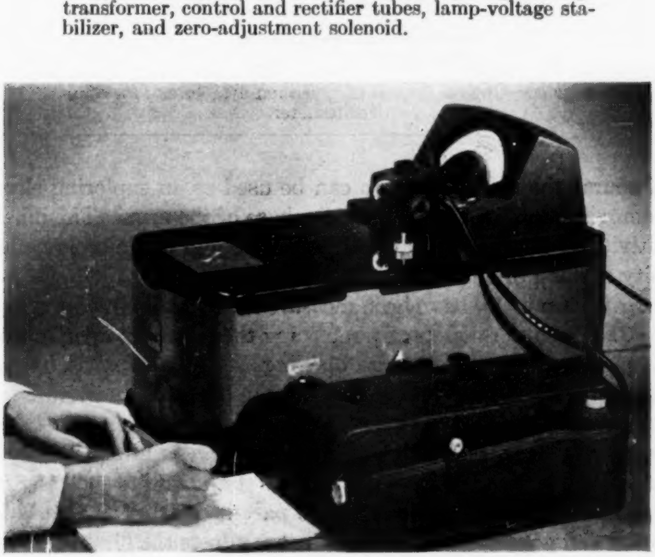

Fig. 15—Liquid-density attachment in use.

sity in the beam to bring the meter reading to 3.0, while the instrument is adjusted to read correctly from 0.0 to 3.0, then setting the filter control to 6 and readjusting the zero control to bring the pointer to 0.0 setting.

The instrument chassis can be seen in Fig. 14. No specially selected, calibrated, or aged tubes are used. The response characteristics of virtually any photomultiplier tube can be compensated to give results which are in agreement with density values marked on the uniformly calibrated meter scale, by simple adjustment of the compensating circuit. The inherent stability of operation is assured by the basic feedback circuit.

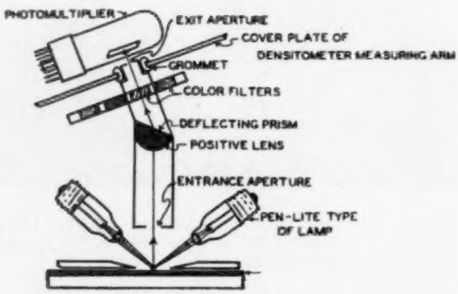

Fig. 16—Optical system of reflection attachment for color densitometer.

Of course the measuring arm can be used as an exploring element by removing the pivot shaft from the base of the arm. The inherent sensitivity of the instrument is between 1.0 and 0.1 microlumen at a density reading of 3.0.

Densities up to 4.0 have been measured through a circular aperture only 0.001 inch in diameter by replacing the standard aperture plate with one having a smaller size opening. An attachment has been designed for measuring the density of liquids and is shown in Fig. 15.

Another attachment permits the reflection densities of solid substances to be measured in color and in black and white. The optical system is shown in Fig. 16. Stray light is eliminated to such an extent that for a typical unit less than one part in 1000 of the specularly reflected component of the incident beam affects the phototube when a first surface mirror is placed in the specimen position.

Fig. 17 shows the head itself and Fig. 18 shows the head in actual use. Fig. 19 shows the spectral-energy-response product curves for the three-color filters used in the reflection head.

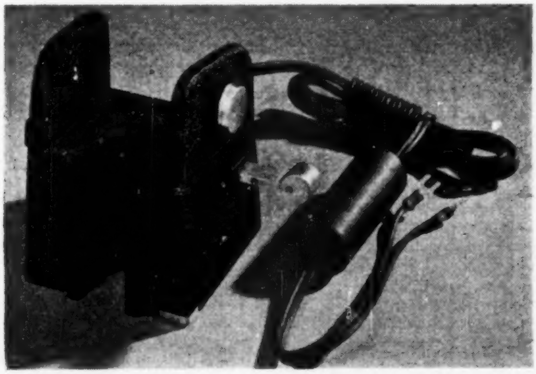

Fig. 17—Reflection attachment for color densitometer.

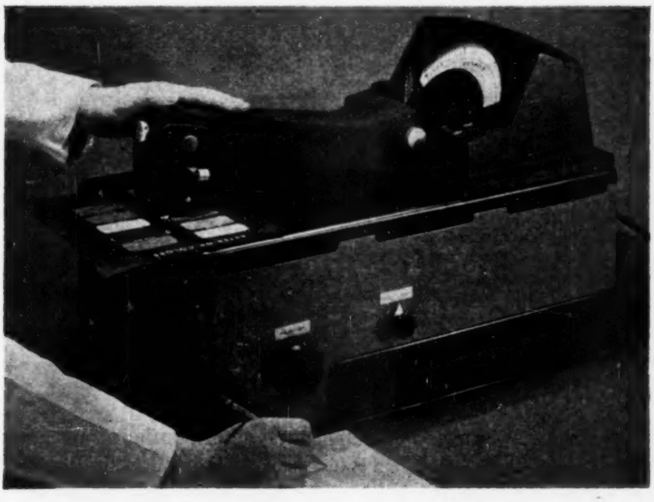

Fig. 18—Reflection attachment for color densitometer in use.

One of the most attractive applications of the instrument is for automatic recording. Since the densitometer is unique in having an

electrical output which is uniform in density it can be attached directly to any standard ink recorder such as the Brown high-speed automatic potentiometer and used as a linear automatic recording densitometer.

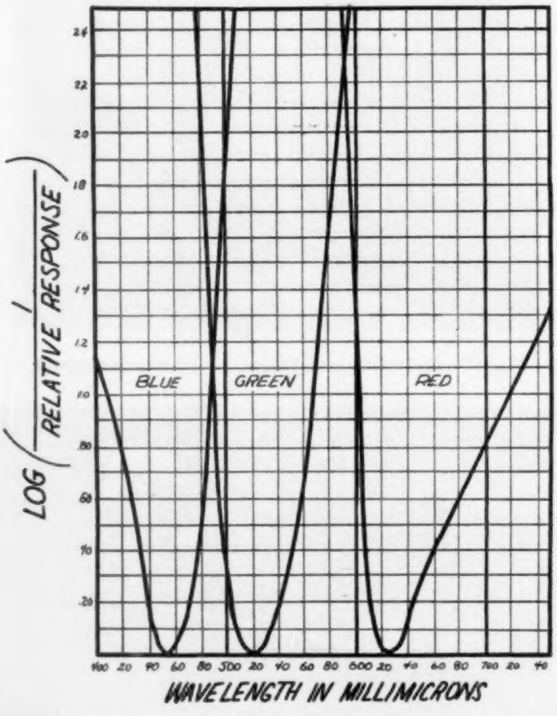

Fig. 19—Log (reciprocal relative response product) curves for filters used in reflection attachment.

Wherever large numbers of sensitometric or similar strips are to be read the use of the automatic recording combination makes analysis faster, more convenient, more fully objective, and therefore more nearly free from error.

Automatic recording systems require "smooth" modulation strips for satisfactory operation. In the case of the Eastman Type II-b sensitometer these may be obtained by masking the steps of the ex-

posing drum with a smooth cover plate* or by using the sensitometer as is and inserting a "repeating" step wedge.†

Fig. 20 shows the instrument with a simple film-drive unit attached to a linear high-speed recorder. Fig. 21 shows a series of three traces for a color-film sensitometric strip. Each trace is recorded in the color corresponding to the color of light at which the measurement was made. Further application of the automatic recording system in the motion picture field will be reported at a later date.

The speed of response is entirely dependent on the characteristics of the indicator since the response time of the photomultiplier tube

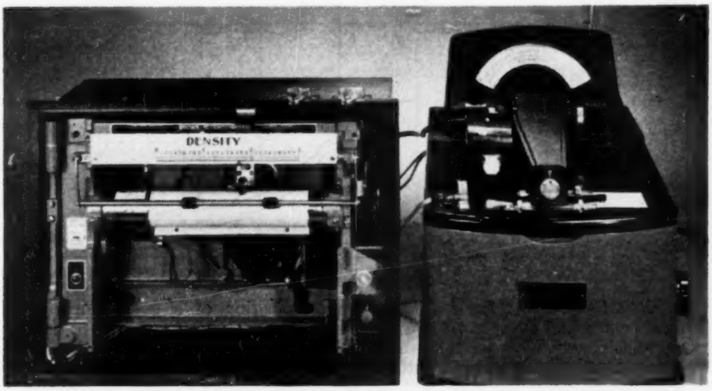

Fig. 20—Color densitometer used in conjunction with Brown high-speed ink recorder for automatically recording color densities. Color of the ink used in making the individual traces corresponds to the color of the isolation filter.

and associated control-tube circuits is of the order of magnitude of milliseconds. Therefore, in automatic recording, the speed of response is limited solely by that of the recorder.

ACKNOWLEDGMENTS

The author is indebted to several members of the Ansco Physics Research Laboratory: Dr. Hoerlin, Mr. Blakeslee and Mr. Alanckos, for their help in developing and testing the instrument, and particu-

* United States Patent, 2,406,702, H. W. Moreall, Jr., 8/27/46.

† United States Patent, 2,457,746, M. H. Sweet, 12/28/48.

larly to Mr. Karl Greif for his assistance and many excellent suggestions which contributed materially toward making it a better instrument.

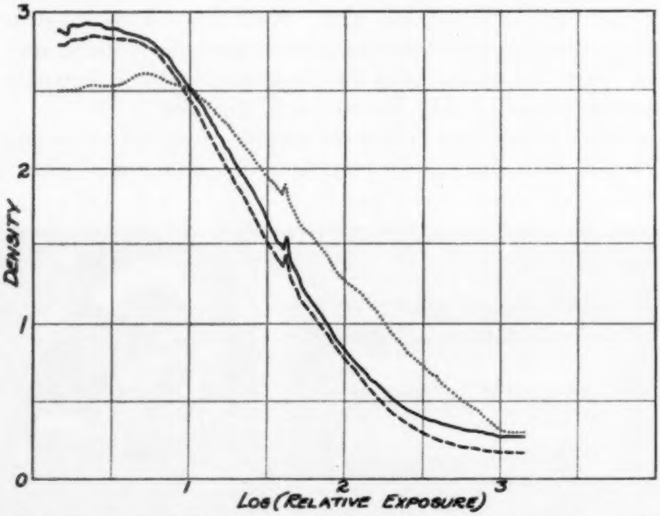

Fig. 21—A direct trace of an actual recording of a color-film strip made using the equipment shown in Fig. 20 (in the original record each curve is drawn with an ink whose color corresponds to that of the isolation filters). The solid line was traced from the blue-ink curve, the broken line from green-ink, and the dotted line from red-ink. Total time for recording three complete traces was slightly less than two minutes (including loading and unloading sensitometric strip and graph sheet). The "pips" in the three curves correspond to a fiducial line exposed on the sensitometric strip itself in order to indicate the alignment of the three traces.

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Color Measurement of Motion Picture Screen Illumination

By R. E. Harrington and F. T. Bowditch

Research Laboratories, National Carbon Company, Inc., Cleveland, Ohio

Summary—**In comparing the color quality of motion picture projector light sources, it is of little value to judge bare screen colors, with no film in the gate. A complete specification of the spectral distribution of the radiant energy is required. Short-cut methods of evaluating and specifying this important property are described, involving the use of red, green, and blue filters to determine the ICI trichromatic coefficients, and, from these, the color temperature. A method of combining direct color measurements on the carbon arc crater from various angles of view to yield the screen color in any optical system of interest is also described.**

The colors appearing on the motion picture screen when color film is in the projector gate are the combined result of the spectral distribution of the radiant energy from the light source and the spectral transmittance of the film. Useful color comparisons of light sources in this service thus require a much more accurate knowledge of their spectral qualities than can be derived from the visual examination of bare screens, with no film in the gate. For example, the white color of a bare screen illuminated by an equal-energy source, with identical radiant intensity at all wavelengths, can be exactly matched, visually, by a hypothetical light source consisting of nothing more than approximately equal parts of sodium vapor yellow (5890 A) and a monochromatic blue (4860 A). Although there would be no visual way of telling from the identically-matched bare screens, it is obvious that color film would look very much better with the equal-energy source.

The real test of a light source in color film projection is thus a visual evaluation of the picture colors finally produced on the screen. Independent evaluation of the light source itself is possible only in terms of the complete specification of the spectral distribution of the radiant energy as related to the transmittance of the film. Such a specification is very useful in many colorimetric calculations, such as those directed toward a determination of what a so-called standard observer[1] would see in any given case. In a previous paper,[2] data

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of this sort were presented for a number of typical projector combinations, and it was pointed out that a close correspondence exists between the spectral distribution of carbon-arc screen light and that of a black-body, heated to the closest color match. As applied to the specification of carbon-arc screen light, therefore, the so-called color temperature of that light has useful meaning in defining in simple terms a spectral distribution of sufficient accuracy for most colorimetric work.

The determination of screen-light color temperature through the measurement of the spectral distribution of this light is, however, a tedious process, so that a simpler means of color temperature determination is desirable. Here we have found the photocell-filter combination suggested by R. S. Hunter[3] of value, in which comparative photocell readings are taken with specially selected red, green, and blue filters. These readings specify the ICI (International Commission on Illumination) trichromatic coefficients, x, y, and z,[1] of the screen color in question, and these may be compared with the corresponding coefficients of black-bodies at various temperatures to find the one most nearly a match. We have confirmed Hunter's finding that it is necessary to calibrate the photocell-filter system directly against light sources of known color quality, similar to those to be measured. For instance, when our cell and filters are calibrated against an incandescent tungsten standard of 2848 K (degrees Kelvin) color temperature, we find that the red filter readings require the addition of an 8 per cent correction to give good values in the 5000–6000 K range of carbon-arc sources.

Figure 1 shows the apparatus employed in these three-color screen light measurements. A photocell with a plain glass window is mounted on a frame, with provision to slide any one of three color filters in front of it. The chain drive shown permits convenient remote operation of the filter slide when the assembly is mounted on top of a pole, in the center of a full-size motion picture screen. From the relative readings obtained with these three filters, the trichromatic coefficients, x, y and z, of the screen-light color are obtained. These in turn are referred to a chart similar to that shown as Fig. 2, which is an expanded section of the ICI color diagram including a portion of the black-body locus, and with iso-temperature lines and uniform chromaticity ellipses calculated after the method proposed by Dr. B. D. Judd of the Bureau of Standards.[4]

As an example, the screen color with the new Hitex[5] 13.6 mm carbon

at 170 amp is plotted at the point A. Following the slope of adjacent iso-temperature lines to the black-body locus gives a color temperature of 6250 K, directly indicated by the scale drawn along the locus. The divisions of this scale are drawn at the halfway points between the indicated temperatures (*e.g.*, at 6225 and 6275, on each side of 6250 K), extrapolations from color points to any point between two divisions being assigned the same color temperature. Our experience in duplicating optical setups and the associated measurements indicates that no greater accuracy, applicable to all commercial

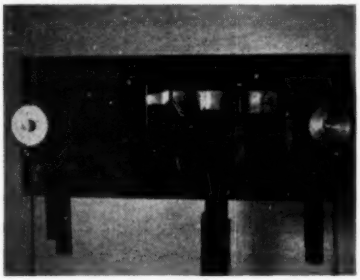


Fig. 1. Photocell-Color Filter Assembly; used to determine the ICI trichromatic coefficients of screen light.

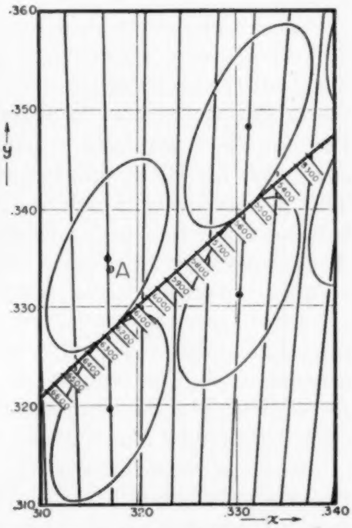


Fig. 2. Section of the ICI Chromaticity Diagram; showing the black-body locus in the range of carbon-arc screen colors, together with the iso-temperature lines and the equal-color-difference ellipses used to evaluate the departure of a given screen color point from the black-body locus.

systems of the type described, is justified, although the mathematics with a given set of data do permit a much closer specification.

The chart of Fig. 2 may also be employed to give a measure of the difference between a screen color of interest, *i.e.*, point A, and the nearest matching black-body color. According to Judd,[4] the ellipses of this chart define the locus of color points 10 units of least perceptible difference (LPD) removed from the color point in the center of the ellipse. Therefore, since the distance between point A and the black-body locus at 6250 K is 9/10 the nearest parallel ellipse radius, the Hitex carbon screen color is said to be 9 LPD from this black-

body color. Such information is useful in evaluating the validity of the color temperature nomenclature in any given case.

It is also of interest to know something of the chromatic nature of such a color difference. To determine this, the line joining the screen color point with the nearest black-body color is extrapolated to the spectrum locus, as in Fig. 3, to give an intercept B defining the spectral nature of the color difference. It is thus determined that the Hitex carbon screen color could be exactly matched by adding about 2 per cent of monochromatic green radiation of 5500 A wavelength to the color of a black-body at 6250 K.

Figure 3 also shows a number of other screen color points with various carbons and optical systems, showing in all cases a close grouping about the black-body locus. Of greater significance in evaluating the validity of the black-body designation, however, are the curves of Fig. 4. These show the complete spectral distribution of radiant energy for the Hitex carbon screen color, together with that of the 6250 K black-body, which most nearly matches it. The difference between the two curves, ordinate by ordinate between 4000 and 7000 A, averages only 3 per cent. For most visual studies, this order of accuracy would seem quite adequate.

Various proposals have been made[6,7] to simplify the foregoing procedure by measuring only two color components of the screen light, associating the color temperature with the ratio of these two readings. Depending upon the accuracy of the calibration, this can be made a quite satisfactory procedure for light sources similar to black-bodies in relative spectral distribution, but suffers from the limitation that the answer is always some exact color temperature, with no indication of the magnitude or chromatic nature of the departure from the black-body locus.

Further, it should be borne in mind that the significance of these findings is confined to the visual spectrum, 4000 to 7000 A. From other studies, we know that the infrared radiation of carbon arcs is much less than that of the visually-matched black-body. Also, the ultraviolet radiation is in general much higher for arcs than for visually equivalent black-bodies, although this is modified in marked degree by the absorption of the glass parts of the optics. Thus, while color temperature designations are useful in studies involving motion picture projection where the human eye is the receiving instrument, they must be used with considerably greater caution in other applications, such as photography, for instance, where the recording sensi-

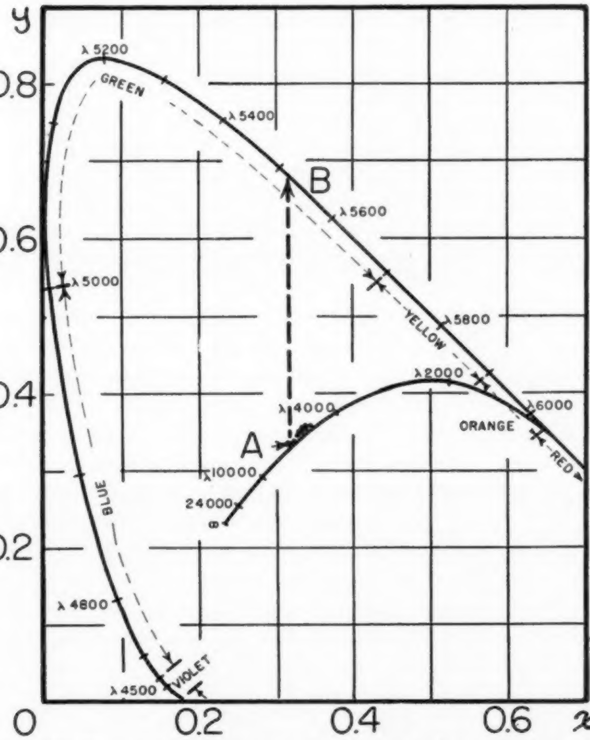
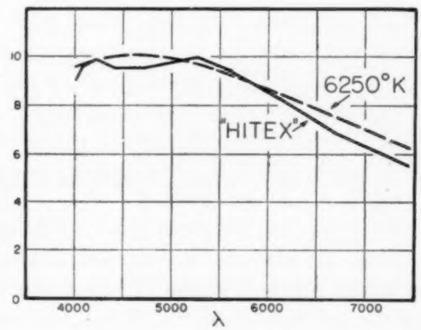


Fig. 3. ICI Chromaticity Diagram; showing typical screen color points with relation to the black-body locus and the locus of spectrum colors.

Fig. 4. Spectral Distribution of Radiant Energy; comparing the screen color with the new 13.6-mm Hitex super-high-intensity carbon at 170 amp with that of a black-body at 6250 K.



tivities vary with wavelength in a manner widely different from that of the eye.

So far, this paper has been concerned with the evaluation of the final screen color, without regard to its origin. It is also of interest to study the characteristics of the source and of the optics which determine this end result. In this connection, it has been pointed out by Jones,[8] among others, that motion picture screen illumination is, in fact, an overlay of many crater images of varying magnification, elliptical foreshortening and orientation, as these things are determined by the different angles with which the source is viewed by the elemental areas of the optical system. In this way, color and brightness variations existing at the source are smoothed over the screen to give a much higher order of brightness and color uniformity than exists over any one direct view of the source itself. This highly important averaging effect can be demonstrated by masking the light collecting element in such a way that the screen light at any instant is confined to that delivered by a single elemental area of the collector element. If, then, this mask is moved about to explore the surface of the collector, the corresponding array of screen light distributions will give a sequence, one at a time, of the individual images in the complex overlay which constitutes the screen illumination. However, in a motion picture projection lamp, it is quite difficult to move such a masking device conveniently about inside the lamp housing while the projector is in operation. Fortunately, a completely equivalent effect can be secured much more simply, entirely outside the projector housing, by locating a pinhole in the light beam at a suitable location in front of the projection lens. Just as a lens of 5 in. focal length will image an aperture plane 5.01 in. distant at a screen 100 ft away, so will this same lens image the elliptical mirror in a Suprex arc lamp, for instance, in a plane a little less than 6 in. in front of the focal point of the lens. Such a mirror image is shown by Fig. 5. A pinhole placed in this image plane will thus limit the screen light to that originating from the small mirror element imaged in the pinhole just as effectively as if all but this area of the mirror itself had been blackened. In order to utilize this effect, the apparatus illustrated by Fig. 6 was constructed. This is adapted to locate a pinhole anywhere over the mirror image of Fig. 5.

Figure 7 shows a typical view of the screen light so obtained, from a mirror segment looking at the crater from a 65° angle. The outline of the aperture image has been emphasized on the negative from which

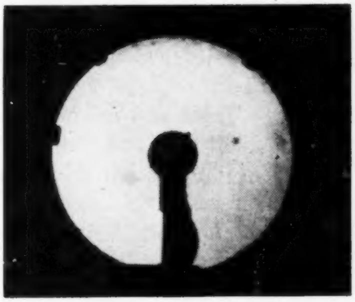


Fig. 5. Image of the Light-Collecting Mirror of a Typical Suprex Carbon Arc Lamp; formed by the motion picture projection lens in a plane close to the front surface of this lens.

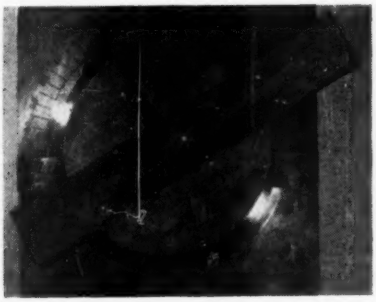


Fig. 6. Pin-Hole Locating Device; mounted in the mirror image plane of Fig. 5, and adapted to restrict the screen light to that originating from mirror segment imaged in the pin-hole.

Fig. 7. Screen Light Contribution of an Elemental Mirror Area; viewing the carbon arc crater from an angle of 65°, and showing the crater imaged elliptically in the center, with the flame light ahead of it to the right; the projection lens fails to pass the shell light behind the crater, which would otherwise have been imaged in the dark section at the left.

this print was made. The elliptically bounded section in the center of the screen is the image of the high intensity crater, which, from this angle of view, does not completely fill the aperture. To the right, the less brilliant light from the arc flame in front of the crater is imaged. The completely dark section to the left indicates that portion of the aperture which receives no usable illumination from the mirror segment under study. In this particular case, light originating from the positive carbon shell on the side of the carbon nearest this mirror segment is reflected through the far side of the film aperture at an angle outside the cone accepted by the projection lens.

The result of summing the illumination of Fig. 7 with that from all the other mirror segments is a rosette-like overlay, with crater images at all possible angles, and with the dim and the dark sections distributed uniformly over 360° around the center of the screen. The very important function of the optical system in thus averaging the nonuniformities of the individual mirror contributions, like Fig. 7, to give the uniformly white screen which characterizes a well-aligned projection system is thus apparent. At the same time, the nonuniformities in color and intensity which result from careless optical alignment, putting the individual images like Fig. 7 off center on the gate to bring in variable amounts of shell and crater light, can be readily visualized.

With the condenser light-collecting optics which are commonly employed with larger carbons at higher currents, the same fundamental considerations apply. The incomplete aperture coverage of Fig. 7 is avoided, however, by the use of a smaller light-collecting angle with a corresponding reduction in the ellipticity of the crater images on the aperture. This advantage is counteracted to some extent by the spherical aberration of the condensers, which images the angular views of the crater somewhat off center on the aperture.

This breaking down of the screen light into its optical components suggests the reverse procedure, previously described by Jones,[8] of measuring the light distribution over the carbon-arc crater region from various angles of view, and then combining these, with proper weighting factors, to predict the projector aperture and screen illumination with any optical system of interest. Since Jones was interested only in evaluating light intensity, he used a conventional Viscor-filtered photocell in all his crater measurements. In the work described here, this procedure was extended to include the use of the clear-window photocell and the red, green, and blue filters used to

determine the ICI trichromatic coefficients of screen light. Thus instead of a single trace of brightness variation across a given crater image, three such traces are obtained, with each one of the three color filters in turn. Each one of these may then be treated as Jones did to give a summation of the corresponding color intensity over the aperture with any light-collecting system of interest.

Figure 8 shows a view of the crater image board, with a clear-window photocell in use. The color-filter slide shown in Fig. 1 is located in the beam near the crater, so that any one of the three filters may be put into the beam. The procedure at the image board is exactly the same as was previously described,[8] except that now three separate sets of intensity variation data are obtained, one with the red, one with the green, and one with the blue filter in the light beam.

Figure 9 shows such data for two angles of view of a typical carbon-arc crater. Through the application of the appropriate magnification ratio of the optical system for each angle, these color intensity variations may be transferred to the plane of the motion picture projector aperture and from there to the screen. Here the appropriate weighting and summation of these with similar data from other angles of view give a prediction of the screen-light color resulting from the total overlay of crater images on the screen.

In accumulating data with this system, a phenomenon was observed which is of some theoretical interest, and perhaps may have practical value in certain types of optical calculations as well. In correlating the color intensity distributions across the crater from several angles of view, an attempt was made to interpret these in terms of a single plane of origin which would produce cosine-law variations matching the observed behavior at various angles. No single plane could be found to satisfy this condition for all three colors, but it was found possible to secure somewhat better correlation with any one color. For instance, referring to Fig. 10, it was observed with the green radiation across the horizontal axis of the crater, that the point of maximum brightness appeared to originate from a point some finite distance inside the crater, 1.3 mm in the case described. Similar consideration of the blue and red components gave apparent origins 0.5 mm and 1.7 mm inside the crater, respectively. Measurements of this same phenomenon, made on several other types of carbons, gave different absolute values, but always in the same relative order. This is in accord with the concept that the coolest region in the crater is next the crater floor, where the vaporization temperature of carbon,

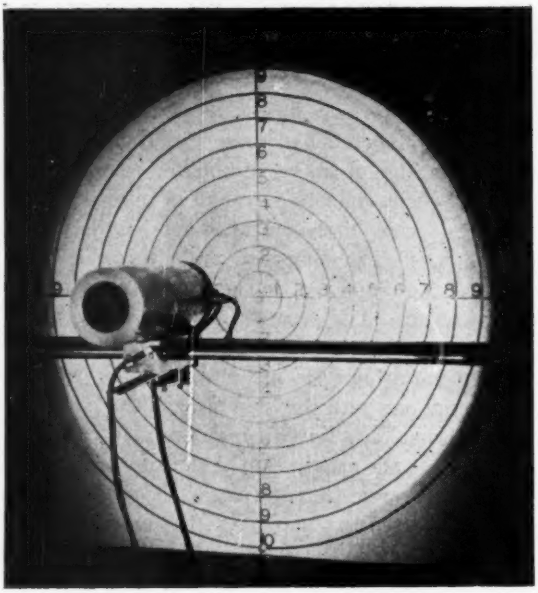


Fig. 8. Crater Image Board; adapted for tracing the red, green, and blue intensity distributions across the crater.

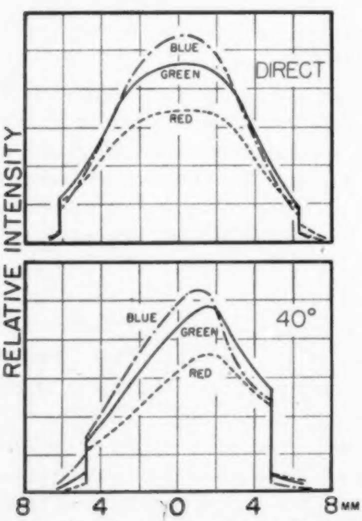


Fig. 9. Typical Crater Color Traces; viewed directly and from a 40° angle.

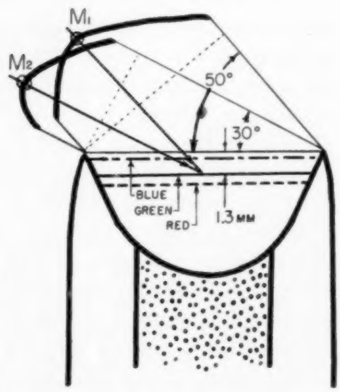


Fig. 10. Crater Color Intensity Distribution *versus* Angle of View; showing the apparent origin of the most intense green radiation at a point 1.3 mm inside the crater; similarly determined positions for the blue and the red radiations are also indicated.

ca. 3900 K, limits the maximum temperature to that value. As the distance from the crater floor increases, within the confines of the crater, so does the temperature of the crater gases. Such a hypothesis explains the occurrence of the maximum intensity for the lowest energy red radiation nearest the crater floor, and that of the highest energy blue radiation farther out in the crater cavity. In terms of screen illumination, these differences are of no practical consequence. They do, however, enhance our theoretical understanding of what goes on in the crater region, and, from that standpoint, contribute to the continued improvement of the high intensity carbon arc as a motion picture projector light source.

In conclusion, it should be re-emphasized that any useful specification of the color of motion picture screen illumination must give a measure of the spectral distribution of the radiant energy involved. Trichromatic coefficients and color temperature values are of interest only in so far as they give such information. With carbon arcs, close correspondence to the black-body type of continuous radiation, with substantial amounts of radiant energy at all wavelengths in the visual region, permits the effective use of this abbreviated nomenclature. It is this same uniformity of spectral distribution which assures the effective reproduction of natural color on the motion picture screen.

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Cinecolor Three-Color Process

By ALAN M. GUNDELFINGER

Cinecolor Corporation, Burbank, Calif.

Summary—**The basic chemical reactions, spectral characteristics of the dyes and types of machines utilized in the film processing are discussed in detail. The entire Cinecolor three-color process is described from the printing of negatives to the final inspection of the finished print.**

The Cinecolor three-color process is a subtractive process whose application is found primarily in the theatrical and commercial fields where many copies from an original are required.

The three-color process is designed for, and depends upon, three-strip separation negatives for its printing medium. These negatives may be obtained from alternate or skip-frame techniques such as are employed in cartoon photography and three-strip beam-splitting cameras; or separations made from monopack films, such as Kodachrome or Anscocolor. Aside from the above, it is not the purpose of this paper to delve into the technique of producing negatives but rather to describe the print process.

Because of the years of experience which the company has had in the two-color field, the controls which have been developed, and economies of operation which have been effected, the three-color process was intentionally developed along the lines of the two-color system. In other words, the attempt was made to develop the three-color method, as much as was feasible, as an extension of the two-color process.

The positive raw stock utilized is the conventional and well-known duplitized film consisting of the usual base with color-blind positive emulsions impregnated with a water soluble yellow dye coated upon both sides of the base. It is of interest to note that this film has exceptionally good projection life, outlasting prints on single coated stock.

Printing

Assuming that three-strip separation negatives are available, the blue record will be referred to as the yellow printer, the green record as the magenta printer, and the red record as the cyan printer. The

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first step in the process is to print two of the records simultaneously onto opposite sides of the positive film. While it is not essential, the common practice is to use the cyan and magenta printers in this first operation. In the same operation, the sound track is printed to the side of the film which is subsequently to contain the cyan image. As a result, the positive raw stock reaches the process department having latent images of the magenta component on one side of the film and the cyan picture component and the sound track on the opposite side. Because of the necessity of maintaining these two picture images in perfect superposition or registration, step printers rather than continuous printers are utilized.

These printers, as illustrated in Fig. 1, have two lamp houses connected to the film gate by means of light tunnels. As can be seen from the illustration, the two separation negatives are brought down through the film gate with their image-containing gelatin coatings facing each other, with the positive film sandwiched in between. Before reaching the film gate one of the negatives, which has been previously edge-notched, passes through a conventional breaker box whose purpose it is to actuate a light-changing device at the instant the change of scene occurs in the printer aperture.

The Cinecolor printing machines utilize push-down pins located just above the aperture rather than the conventional pull-down pins which are usually present below the aperture. Because of this, the wear and tear on the perforations utilized for registration is minimized because, no matter how badly shrunk the negatives might be, the registration pins of the printers are caused to enter sprocket holes in the film which are no more than a small fraction of an inch away from the holes utilized for advancing the film. In this manner no punching can occur with the registration pins and, as a result, it is the rule, rather than the exception, that the steadiness and excellent image superposition of the five hundredth copy is identical with that of the first copy.

The light-change device employs a continuous loop of opaque leader stock which has punched in it holes of variable but predetermined size. This leader stock is advanced automatically by means of a solenoid-actuated sprocket which, in turn, is controlled by an electrical contact which occurs when the notch in one of the negatives referred to above reaches the breaker box. In other words, this might be referred to as a variable area type of light changer. As shown in Fig. 1, the film, after leaving the picture aperture, continues on down to where it is

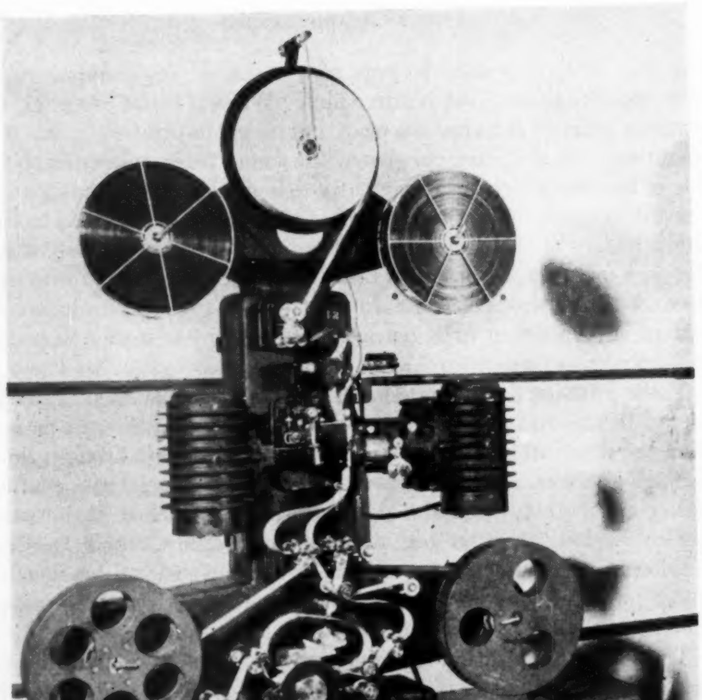

Fig. 1. Release printer.

met by the sound track negative and both of these films are passed over a continuously rotating conventional sound sprocket containing the typical sound aperture which is illuminated from a lamp house below.

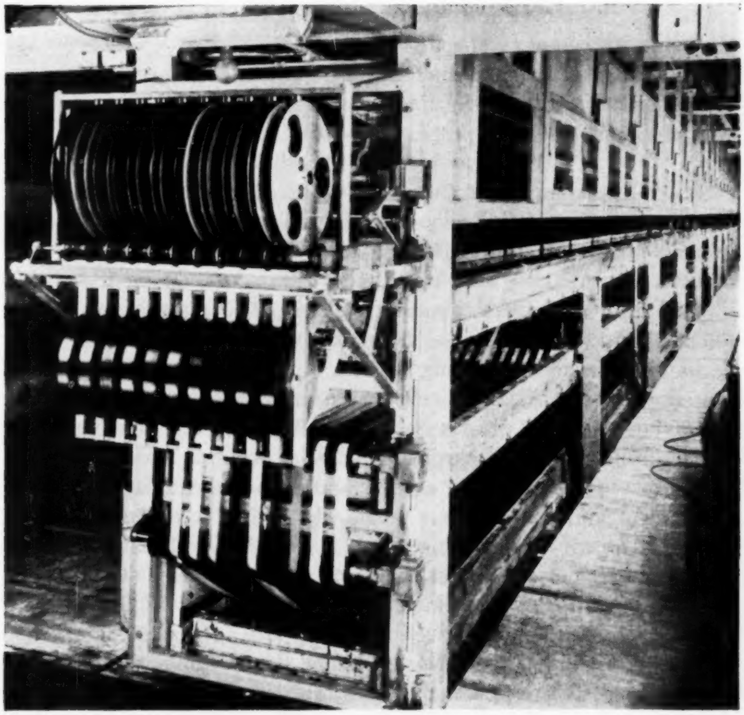

Fig. 2. Color process machine.

PROCESSING MACHINES

The present processing machines consist of three horizontal shallow troughs, one above the other, and wide enough to accommodate ten strands of film, as illustrated in Fig. 2. The immersion time in each solution and wash is held constant and the duration is controlled by the spacings between partitions or dams. The flow rates of the solu-

tions and washes, as well as temperatures, are held constant. The wash water utilized in the process is brought up from several deep wells, properly filtered and passed into the main distribution tank. It is extremely fortunate that the temperature of this well water remains quite constant throughout the year, varying between 64.5 F and 65.0 F.

Each of the ten strands of film on the processing machine, while operating at constant speed, is, nevertheless, independent of the others. In other words, each strand can be started or stopped independently at will. The linear speed of each strand is 12 ft per min, making a total output capacity for each machine of 120 ft per min.

As can be seen in Fig. 2, the rolls of printed film are loaded on a rack and the rotation of the rolls is facilitated by means of ball-bearing spindles which are slipped through the film roll hub and which, in turn, fit into a sloping slot in the rack. It should also be noted that the take-up reels for each strand are directly above the corresponding roll of film in the rack so that the entire operation of the machine can be handled from the loading end. The take-up reels are made of Bakelite and the variable speed take-up is accomplished very simply by having these reels rest upon two rapidly rotating Bakelite spools placed on adjacent and parallel-driven shafts.

The driving sprocket for each strand is just ahead of the take-up mechanism and on the same level. As a matter of fact, for each strand there are two driving sprockets on adjacent parallel-driven shafts and by means of idler rollers on a swivel bracket the film can be held down against either of the driving sprockets. One of these sprockets contains 35-mm teeth and the other sprocket has 16-mm teeth but spaced laterally the same as on the 35-mm sprocket. This makes it possible to operate any strand with 35-mm, 16-mm, or 8-mm film interspliced in any manner. This is due to the fact that, in the substandard field, Cinecolor utilizes 35-mm width film with multiple rows of either 16-mm or 8-mm perforations so that it becomes necessary only to flip the pivoted bracket when a splice between 35-mm film and either of the two substandard films appears at the driving mechanism. While it is perfectly possible to operate the machine with this single driving mechanism, it is the practice, however, to safeguard the machine operation with several friction booster drives at the two ends of the machine in order to prevent the possibility of strands snapping due to build up of tension.

As can be seen from the photograph in Fig. 2, the film enters the machine in the top trough and progresses down the entire length to the other end of the machine where it passes over the end and down into the middle trough, where it is then going in the opposite direction. When the film reaches the driving end of the machine, it passes over the end of the trough and down into the third or bottom layer, where it is then progressing in its original direction. When it reaches the far end of the machine again, it comes out of the bottom trough past a double set of air squeegees and then progresses up into the dry box which extends the entire length of the machine. The film then moves back toward the head end where it passes through the driving mechanism and onto the take-up reel.

This very brief description of the Cinecolor process machine applies to all of the machines utilized by Cinecolor in its positive processes, with one minor exception. The three-color process involves two stages. Because of the simplicity of the first stage, which requires only a few solutions, the length of the machine permits it to be operated at twice the speed of the other machines, and thus to supply two machines utilized for the second stage of the process. To be more explicit, each machine is in itself a complete unit with respect to the two-color process, but in the three-color process three machines will do the work or create the output equivalent to two machines in the former process.

FIRST PROCESSING STAGE

When the film first enters the machine it is immersed in a conventional developer where the sound track, cyan, and magenta images are developed into silver. After a thorough wash the film is then passed by an air squeegee which blows off the excess moisture from the magenta side of the film. From here it is laid cyan down onto a solution whose purpose is to convert the sound track and cyan images into a cyan pigment. While the chemical reactions involved in this step of the toning operations are manifold and somewhat complicated, they can be illustrated in rather simple terms by the following equations:

$$\underline{4\ Ag} + 4\ K_3[Fe(CN)_6] \rightarrow \underline{Ag_4[Fe(CN)_6]} + 3\ K_4[Fe(CN)_6] \quad (1)$$

$$2\ Fe_2(SO_4)_3 + 3\ K_4[Fe(CN)_6] \rightarrow \underline{Fe_4[Fe(CN)_6]_3} + 6\ K_2SO_4 \quad (2)$$

Equations (1) and (2) may be combined to show the complete reaction as follows:

$$\underline{4\ Ag} + 2\ Fe_2(SO_4)_3 + 4\ K_3[Fe(CN)_6] \rightarrow \underline{Ag_4[Fe(CN)_6]} + \underline{Fe_4[Fe(CN)_6]_3} + 6\ K_2SO_4 \quad (3)$$

The above equations indicate that the reaction takes place primarily between the silver of the image, potassium ferricyanide, and a ferric salt, and that the end products of the reaction consist of silver ferrocyanide, ferric ferrocyanide (Prussian blue) and potassium sulfate.

In addition to these reactive agents the toning solution of course contains other materials which, because of ionization equilibria and the formation of complex ions, can control the availability of the reactive ions and consequently the quantity and character of the Prussian blue deposit which is formed. It is perfectly possible to control contrast and the degree of dispersion of the ferric ferrocyanide deposit by varying quantitatively and qualitatively the composition of the toning solution. It is possible to form a coarse grainy agglomeration which produces bad grainy effects on the screen as well as the destruction of resolution and definition, or it is possible to produce a colloidally dispersed deposit which is highly transparent, free from grain, and having high resolution characteristics. It is also possible to go beyond this point and produce such a high degree of dispersion that bleeding takes place, causing once again the loss of resolution. Once all the factors are known and properly controlled, it is a simple matter to form a cyan image which has excellent grain and resolution characteristics. In addition to this, the spectral quality of this type of image is good from the standpoint of three-color reproduction, as may be seen by reference to Fig. 3. A more complete discussion of the spectral characteristics of this image will be given later.

It will also be noted from the above equations that the silver which forms the original cyan image has at this stage of the process been converted to an insoluble silver salt, namely, silver ferrocyanide, which salt is both light insensitive and spontaneously developable if brought into contact with a developing solution.

When the cyan image has been completely converted in the solution referred to above, the film then passes into a wash where the unreacted toning solution is completely removed from the film, after which the film is immersed in another solution whose purpose is to

convert the silver ferrocyanide to silver bromide. At this stage the silver of the original cyan image is in the form, namely, silver bromide, where it was prior to the printing operations, with the exception that the original silver bromide crystalline structure has been destroyed. This reformed silver bromide is neither subject to spontaneous development nor is it particularly light sensitive.

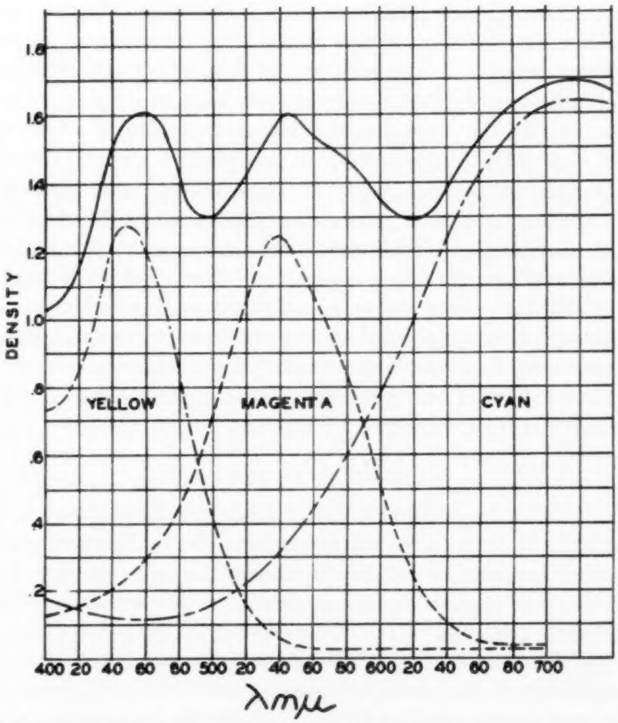

Fig. 3. Spectral-density characteristics of yellow, magenta, and cyan components.

It is possible, however, by controlling the character of the ferric ferrocyanide deposit surrounding these particles of reformed silver bromide to produce a degree of photographic sensitivity which is higher than that of the original silver bromide grain which existed in the raw unprinted form. By controlling further the character of the ferric ferrocyanide deposit it is possible to vary the sensitivity of the

reformed silver bromide in such a manner that this sensitivity is increased in direct proportion to the decrease in exposure brought about by the masking effect of the ferric ferrocyanide image. In other words, if one were to flash expose the film containing a cyan image the amount of latent image present in every part of the picture would be constant and this constant image could be brought up into silver by subsequent development just the same as though there were no cyan image present. This is an important consideration in view of the fact that later on in the process it is desirable and necessary to produce an additional image on the cyan side of the film without interference from the cyan image already present.

Upon leaving the solution last mentioned, the film is washed again, properly hardened, and given a final wash before it enters the dry box and is subsequently removed from the machine. The carefully controlled drying operation produces no appreciable shrinkage in the film because of the protection afforded the base by the coatings on each side. When the film comes off this first machine it has on one side an unfixed photographic emulsion containing a silver image of the magenta component and on the opposite side a cyan image imbedded in a complete photographic emulsion whose characteristics are such that the effective sensitivity of the entire surface is constant irrespective of the presence of that image.

Second Processing Stage

The next step in the process is the printing of the yellow component through the yellow printer negative. At present, this printing operation is accomplished on machines similar to those described above. When this operational step is completed the film is ready for its final processing. It should be remembered that the yellow dye with which the emulsions of the film were originally impregnated was leached out of the film in the first developing stage so that in the second printing operation some of the light to which the film is sensitive has penetrated through to the opposite side. In order to overcome this deleterious effect, the film is floated on the developer, the first solution of the second processing stage. This brings up the yellow component in silver on the cyan side of the film and the portion of the image which has penetrated through to the opposite side is allowed to die as a latent image.

It should be noted at this point that the floating operations involved in this process present no problems due to the fact that it is possible

to maintain high surface tension characteristics in the corresponding solutions. It is only on rare occasions that any trouble is encountered and this is due usually to raw stock defects. After leaving the developer, the film is washed and then proceeds into a hypo solution where the undeveloped silver bromide is dissolved and removed from both sides of the film. Following this, the film is again washed. Next in the process a bleach or oxidizing solution is used to convert the silver in the yellow and magenta component images to a dye mordant. Like the cyan toning step, this one involves a group of somewhat complicated chemical reactions which can be condensed and stated quite simply in the following equation:

$$\underline{2\,Ag} + I_2 \rightarrow \underline{2\,AgI} \qquad (4)$$

As can be seen from this Equation (4), the bleaching solution contains iodine as a principal reactant, which combines with the silver of the image to form an insoluble silver iodide image that has the property of absorbing basic dyes. As in the case of the cyan toning operation, by controlling the concentrations of several of the constituents in this bleaching bath the degree of agglomeration or dispersion of the silver iodide deposit can be varied at will and controlled. It is quite evident that if the deposit is coarse the final image will have a high degree of opacity. This is due to the mordant itself and to low color saturation, not only because of the neutral component introduced by the mordant, but also because of the low saturation of the image with dye due to a high volume-to-surface ratio of the silver iodide particles.

On the other hand, the mordant image can be made so highly transparent that it is hardly visible prior to the dyeing operation, and, since the deposit consists of extremely small particles and the surface-to-volume ratio is high, the amount of dye absorption is very much greater. In this case, with the mordant having practically no opacity and with a high dye concentration in the image, the saturation of the color components is excellent. As in the cyan toning step, it is also possible to overshoot in this direction so that bleeding can occur, which of course destroys resolution.

When the bleaching step just referred to has been completed and the film has been washed, the magenta side of the film is blown off by air squeegees and the film is then floated on the yellow dye. Upon emerging from this solution, the film is washed again for a short period of time and is then passed by air squeegees to remove the excess moisture from the yellow side of the film in order that the magenta

side may be floated upon the magenta dye solution. After a final wash, the film is run through the dry box and emerges as a finished three-color print.

Spectral Characteristics

The characteristics of the Cinecolor three-color process may be best demonstrated by reference to Fig. 3 which shows the spectral density characteristics of the three components balanced to equal analytical densities.[1] It is of interest to note that the peak density of the yellow component occurs at wavelength 445 $m\mu$, which corresponds closely to wavelength 440 $m\mu$, which is commonly weighted because of the spectral sensitivity of the human eye, and that the peak density of the magenta component corresponds to 540 $m\mu$, which is also weighted for the same reason.

In the case of the cyan component, however, the density continues to rise beyond the weighted wavelength of 640 $m\mu$ into the infrared. This characteristic is responsible for the high fidelity reproduction obtainable with Prussian blue sound tracks when used in conjunction with the caesium photocell whose peak sensitivity is in the infrared. Still concentrating on the cyan component, it will be noted that the density at 540 $m\mu$ is slightly higher than that at 440 $m\mu$, which is the worst defect in the entire process. The degree of imbalance at these two wavelengths, however, is negligible, as evidenced by the high fidelity of color reproduction in this system. The result to be expected from this small defect is a slight reduction in the brilliance of green objects in the picture. This, however, becomes somewhat advantageous with respect to the possibility of obtaining good sound reproduction utilizing the potassium S4 photoelectric cell in sound reproducers. The over-all peak sensitivity of this type of cell, when used with incandescent exciter lamps, occurs in the green portion of the spectrum and by actual tests it has been found that the Prussian blue sound track with a slight modification of print density or sound negative gamma is just as satisfactory with this as with the caesium type cell.

It can be said, therefore, that the cyan component of the Cinecolor three-color process, while not perfect, is satisfactory. In the case of the yellow and magenta components, it can be observed in Fig. 3 that these two are excellent. The high degree of spectral quality of these three components may be illustrated in a different manner, namely, by observing the fact that the integral densities[2] of the three

components at their corresponding weighted wavelengths are in almost perfect balance when the analytical densities of the three components are identical. In other words, as shown in Fig. 3, the analytical densities of the three components are adjusted to the value 1.45. At the same time the integral density of the yellow component at 440 mμ is 1.24, that of the magenta component at wavelength 540 mμ is 1.24, and that of the cyan component at wavelength 640 mμ is 1.23.

It may be of interest to state at this point that the conversion factors from densities, as read on the E.R.P.I. densitometers, to analytical densities are 1.20, 1.30, and 1.40 for the cyan, magenta, and yellow components, respectively, when read through the Kodak Wratten 29, 61N, and 49 filters. As a result of the excellent balance between the E.R.P.I. densities of the three components and also between the integral densities at the weighted wavelengths when the three components are adjusted to equal analytical densities, it is evident that the process is capable of reproducing very accurately colors as well as neutral values. For example, if it were required to photograph a scale of reds which would be composed of yellow and magenta on the color print, the dominant wavelength of the scale should remain constant throughout. If it were necessary to maintain, for example, a low yellow integral gamma in order to compensate for a small density peak in the blue portion of the spectrum resulting from an imperfect magenta component, then a scale of reds would appear either red in the low densities and magenta in the higher densities or red in the higher densities and orange in the low densities. In addition to this, if the same condition prevailed as stated in the previous sentence, it would be impossible to reproduce accurately a scale of yellow densities since the heavier yellow densities would be lacking in saturation or conversely the lower densities would be too high.

In order to obtain a system which is capable of giving excellent picture reproduction both as to neutral and colored objects, it is essential that the spectral density characteristics of all of the components be of such a nature that a simultaneous balance will occur not only between the analytical densities or gammas but also between the integral densities or gammas. At the same time, the conversion factors between analytical and integral density or gamma should be as close to unity as possible. It has already been noted above that the integral densities are in almost perfect balance for equal analytical densities

and the ratios between analytical and integral densities are 1.45:1.24, 1.45:1.24, and 1.45:1.23, for the yellow, magenta, and cyan components respectively. These ratios are approximately 1.17. Qualitatively it can be seen from the curves in Fig. 3 that there is very little density of the cyan and magenta components in the blue portion of the spectrum, very little density of the yellow and cyan components in the green portion of the spectrum, and very little density of the yellow and magenta components in the red portion of the spectrum. This makes for brilliance and high saturation of color, when desired.

The wavy neutral curve shown plotted above the spectral density curves in Fig. 3, when evaluated by means of the trichromatic coefficients[3] indicates that the neutrals should appear to be an excellent visual gray, and this fact is supported by actual screen tests. The trichromatic coefficients for a high intensity projection arc have been found to be: $x = 0.3408$ and $y = 0.3583$. Trichromatic coefficients for the arc as seen through the Cinecolor three-color neutral are: $x = 0.3533$ and $y = 0.3423$. Taking the point located by the trichromatic coefficients for the arc as the white-point, the dominant wavelength of the visual gray is 538 *C* millimicrons, and the purity 6.25 per cent—a most adequate neutral. It can readily be seen that these values can be plotted as a point very close to the center of the Maxwell curve.

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New Projection Lamp and Carbon-Feed Mechanism

By J. K. ELDERKIN

Forest Electronic Company, Inc., Newark 2, N.J.

Summary—**This paper describes a new carbon-arc projection lamp employing an electronic system to provide automatic control of the carbon positions. Each carbon-feed mechanism is separately driven by an alternating-current motor actuated by an electronic impulse generator. Feeding speed of the carbons is controlled by varying the resistances through the generator control circuits to adjust the number of impulses supplied per minute to the alternating-current motors according to the carbon-consumption rates. A polarized directional electromagnet controls the position and shape of the tail flame.**

Theater motion picture projection requires a highly concentrated, high-intensity light source to give the greatly enlarged image sufficient screen brilliance. The carbon arc is the only light source so far developed capable of supplying the necessary screen illumination. In the past forty years or more this arc source has undergone many changes both in the lamp mechanisms and in the carbons themselves, with resultant marked improvement in the quantity and quality of the light produced.

In order to provide the constant screen light necessary to satisfactory projection, close control of the carbon positions is essential particularly in the reflector-type high-intensity carbon-arc lamp. The lamp must provide three main features: (1) The positive crater must be held in exact focus. (2) The carbons must be fed together at the same rate at which they are consumed. (3) A magnet must be provided to minimize the effects of the magnetic field set up by the direct-current supply to the arc and to stabilize the position of the arc tail flame.

In the direct-current arc, the rate of carbon consumption varies according to the type and diameter of the carbons used, the current at the arc and the length of the arc gap. Since the positive carbon is consumed at a much faster rate than is the negative carbon, conventional lamps employ two feed mechanisms, one driving the positive carbon carrier and the other, the negative. Usually the two carriers

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are propelled by feed screws driven from a single direct current motor through speed reduction gears, clutches, ratchets, and cams. The cam or ratchet mechanism provides a means of regulating the travel speed of the individual carriers, while a rheostat regulates the overall speed of the single driving motor.

In general, these motor-driven feeding mechanisms do not maintain the crater of the arc in correct focus for any considerable length of time, and, as the crater face of the positive carbon wanders from its exact focal point, the light on the screen changes in color and intensity. Further, these mechanisms do not maintain a constant arc length, slight changes in the arc current or voltage resulting in changes in the motor speed which cause the feed mechanism to run too fast or too slow. Manual adjustment of the speed of one feed mechanism is unsatisfactory since such adjustment also affects the speed of the other carbon-feed mechanism.

To overcome these difficulties a new lamp has been developed which uses a separate drive-and-feed mechanism for each of the carbon carriers. Each carrier is driven by a nearly constant speed alternating-current motor energized intermittently by pulses fed from independent impulse generators. Any desired feeding speed can be obtained merely by adjusting the number of impulses per minute fed to the motor, so that almost micrometer adjustment of speed can be obtained, making it possible to hold the arc gap constant and maintain the arc in exact optical focus with the reflector-and-lens system to suit any required consumption rate of either positive or negative carbon.

Fig. 1 shows the complete positive carbon carrier with the cover removed. Fig. 2 shows this carrier in alignment with the negative carbon carrier, also with cover removed, and illustrating the motor, motor reduction gear, worm screw, carrier with side clamp, and carbon clamp. The carbon holders are full-floating and self-aligning, and are provided with fixed-pressure spring-tension clamps. The negative carbon guide and holder is adjustable both vertically and horizontally and, generally, is positioned so that its center is in line with the bottom edge of the positive carbon crater. To strike the arc the carrier is brought forward by pushing in the handle at the end of the worm screw. After the arc is struck, the carrier springs back to provide the proper arc gap. The motor drives the worm shaft through a friction clutch. For manual adjustment of the carbon positions, the worm shaft is turned against the friction of the clutch.

In order to secure the desired precision in carbon-feed control, it was necessary to develop a very accurate electronic impulse generator for supplying the energizing impulses to the alternating-current feed motor, and to incorporate a means for readily varying the number of impulses per minute between the upper and lower speed requirements for feeding the carbon being consumed. This generator is energized

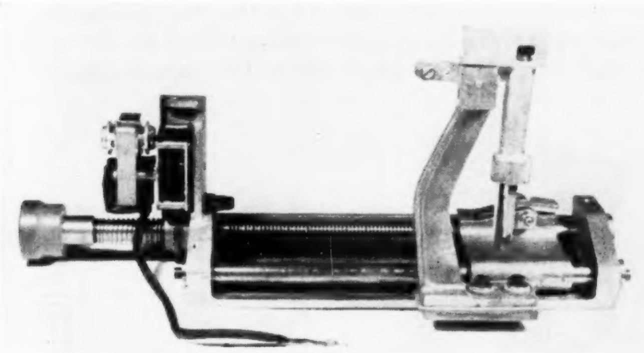

Fig. 1

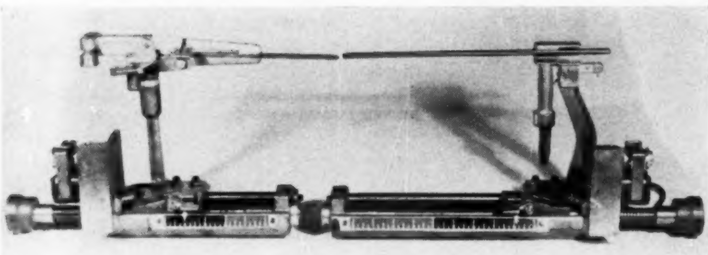

Fig. 2

from the 110-volt illuminating-current supply. It employs a small Thyratron tube, Type 2D21, in circuit with capacitors and resistors in such manner that the time cycle during which the current flows and ceases to flow may be regulated at will, simply by increasing or decreasing the amount of resistance in the control circuit. By merely turning the knob of the variable resistor clockwise or counterclockwise, the number of impulses from the impulse generator will be

increased or decreased. The impulse generator delivers its impulses to the actuating coil of a relay which by the opening and closing of its contacts intermittently connects the alternating-current motor with the 110-volt alternating-current supply. Any arc-voltage change does not alter the feeding speed as is the case when a direct-current motor is used, because the alternating-current motor is actuated from an entirely independent circuit. Thus the actuation of the alternating-current motor and associated feed mechanism can be controlled perfectly and accurately in order to feed the carbon forward at an exact rate. By the use of one of these impulse generators for

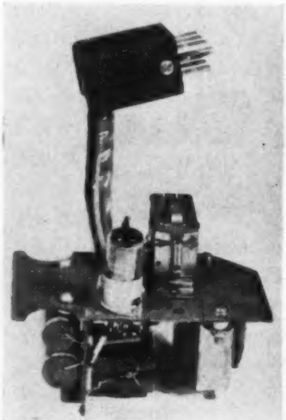

Fig. 3

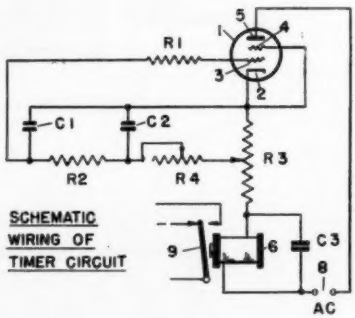

Fig. 4

operation of the negative-carbon feeding mechanism and another for the positive-carbon feeding mechanism, a separate and accurate control of each is obtained.

Fig. 3 is a view of one of the electronic timers showing the Thyratron tube, transformer, capacitors, and resistors in circuit, the relay for opening and closing the motor circuit, and the connector plug, which automatically makes all electrical connections.

Fig. 4 is a schematic circuit of the electronic impulse generator and Fig. 5 is a schematic of the electrical circuits employed in the projection lamp.

Fig. 6 shows the relay which prevents the lamp feeding mechanism from operating when there is no arc between the carbons. This is

accomplished by using a series coil in the arc-supply circuit to actuate the relay, the contacts of which open and close the motor circuits.

In all arc lamps of this type a magnetic field is set up from the direct-current supply to the carbons which has a marked effect on the burning characteristics of the arc itself. Heretofore, it has been the

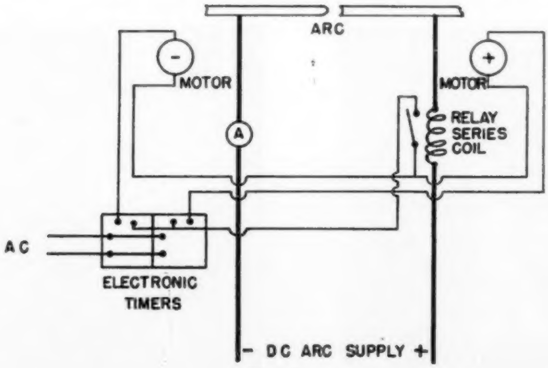

Fig. 5

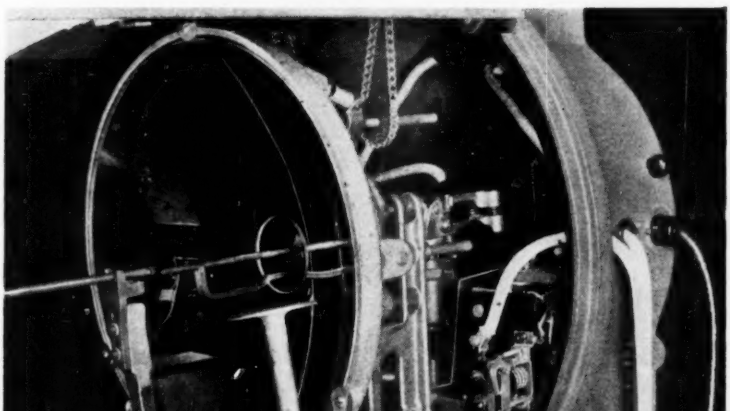

Fig. 6

practice to place either a permanent or electromagnet in the lamphouse, positioned in a manner so that this inherent magnetic field is partially neutralized to give a better burning characteristic to the arc. This type of arc is called a "Suprex" arc and also a "Simplified High-Intensity" arc. While it is a great improvement over the previous

Fig. 7

Fig. 8

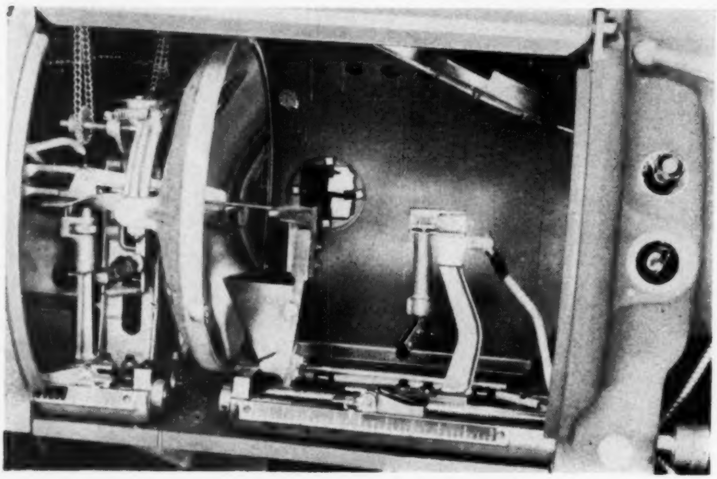

Fig. 9

type of arc known as low intensity, it is still not the ultimate to be desired for very large theaters.

In the lamphouse used with the new feeding mechanism described here, a polarized directional electromagnet is provided. This supplies a strong polarized magnetic effect which causes the arc to burn with a very long and narrow tail flame rising straight up at right angles to the arc and with little enveloping flame. Fig. 7 shows the shape of the tail flame as compared with that of the "Suprex" arc shown in Fig. 8. The magnet is shown in Fig. 6 (bottom center). The horn of the magnet has a target at its upper end and it may be

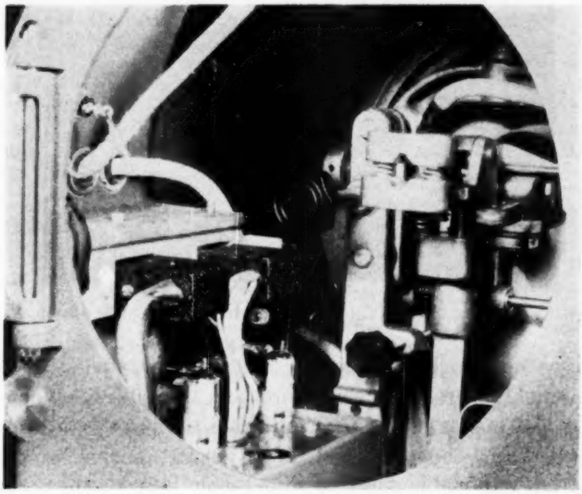

Fig. 10

adjusted vertically or horizontally on its axis. Once the magnet has been initially set up, no further adjustment is necessary, through the complete amperage range of the arc (40 to 90 amperes).

Other features of the lamp design include a warning light which indicates when the carbon has burned beyond the point at which it will last through another reel of film. Both carbon carriers also have scales and pointers indicating remaining burning life.

Fig. 9 shows the working side of the lamp with the door open and the flame shield raised. Fig. 10 is a view through the back door of the

lamp showing both electronic timers with covers removed. Fig. 11 is a side view showing control knobs for adjusting the carbon feeds. All the electric wiring in the lamp is shielded and the wire covered with asbestos braid. The reflector is elliptical, 14 inches in diameter for currents to 75 amperes and 16 inches for currents from 75 to 90 amperes, with a center hole $2^1/_2$ inches in diameter through which the

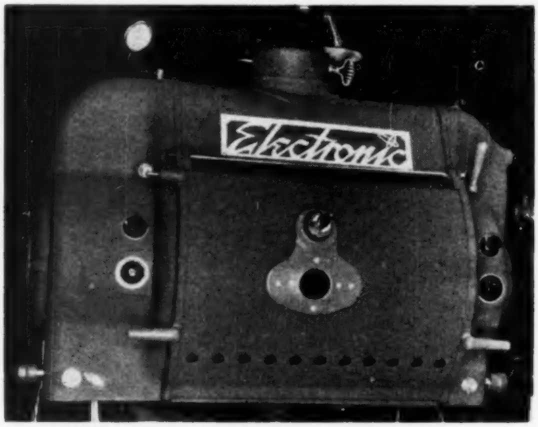

Fig. 11

negative carbon, carbon holder, and carbon guide pass horizontally. A flame shield is provided which protects the reflector when the arc is struck, and moves out of the way when the light gate is opened to pass the light to the projector. The positive carbon guide is provided with a removable chute or shield which carries the copper drippings from the carbon into an easily removable receptacle.

Industrial Sapphire in Motion Picture Equipment

By WALTER BACH
Berndt-Bach, Inc., Los Angeles, California
and
CHRIS WAGNER
Elgin National Watch Company, New York, N.Y.

Summary—This paper is an endeavor to call attention to an engineering material which has the most favorable coefficient of friction in relation to film emulsions and bases among known commercial products.

Characteristics of sapphire in fine watches, the development of industrial sapphire, and potential motion picture equipment applications are discussed briefly. The Auricon camera film gate with regard to the use of hard contact points and the mounting of sapphire contact surfaces is described and illustrated. Physical characteristics of sapphire are shown with charts and performance data. Diamond lapping compounds and the metal bonding and flame forming of sapphire are briefly mentioned.

Synthetic sapphire jewels have the most favorable coefficient of friction in relation to film emulsions and bases among known commercial products. This friction characteristic is due to sapphire's monocrystalline structure and complete lack of porosity, coupled with extreme hardness and resistance to abrasion.

The value of these physical characteristics has been demonstrated for over a century in the jeweling of fine watches, first with natural stones, and of late years with synthetic sapphire which is comparable in hardness and not subject to the flaws found in the natural product.

Every individual who possesses a fine watch carries from seven to twenty-one pieces of sapphire on his person daily, with scarcely a thought that these sapphire jewels represent the most accurate and certainly the most dependable and enduring components of the time-measuring mechanism.

Many engineers are familiar with the amazing magnitude of balance oscillations and escapement action of a watch, but few realize that, in spite of 432,000 impulse and locking cycles each day, the sapphire pallet stones show no wear in a lifetime of service.

Industrial sapphire, or corundum, has been man-made for some fifty years and until the last few years was largely a European product

Presented: May 20, 1948, at the SMPE Convention in Santa Monica.

limited in scope of application by the small size of available raw material. Under the impetus of war demands for jewel bearings, industrial or synthetic sapphire is now produced commercially in the United States.

Industrial sapphire is an artificially grown crystal, formed through an oxygen-hydrogen flame. The alumina, melting and impinging on a refractory pedestal in a high-temperature furnace, grows as a boule or a rod according to the rate at which the pedestal is withdrawn. Rods are commercially grown over a range of diameters to slightly over 0.250 inch and between 2 and 6 inches in length. Boules are roughly 0.750 inch in diameter, limited in length, and average about 200 carats. Tubing, disks and other shapes have been produced experimentally and boules as large as 800 carats have been grown.

Fabrication is primarily by diamond-charged saws and laps, with a relatively new technique of flame forming and flame polishing finding increasing application.

The question now is whether industrial sapphire can find a place for itself in motion picture equipment. The potential motion picture applications fall roughly into four classifications: (1) Where the material is urgently needed because of partial failure of existing components, resulting in danger of film damage. (2) Where film footage is sufficient to indicate marked economy in terms of greatly increased life of film or machine components. (3) Where an additional safeguard could be afforded against film-base scratches and emulsion pickup. (4) Where a design advantage is afforded in the mechanism entirely apart from contact of sapphire itself.

Let us consider current research applications of sapphire in the film gate of the 16-mm "Auricon-Pro" single-system sound-on-film camera.

The Auricon camera has a claw intermittent and it is necessary that the pressure plate maintain the negative in a steady position as the claw leaves the perforation and throughout the time of shutter opening in order to secure a steady in-register picture. It is also necessary that the pressure plate take out the natural film curl and hold the film flat and perfectly in focus at the aperture. This means that one must exert confining forces on the film during shutter opening, and since the pressure plate is of the spring-loaded, constant-pressure type, those same forces are present during the pulldown cycle. To prevent scratching of acetate film base and picking up of emulsion the friction coefficient of the gate must be favorable to the film.

Fig. 1—16-mm "Auricon-Pro" single-system sound-on-film camera.

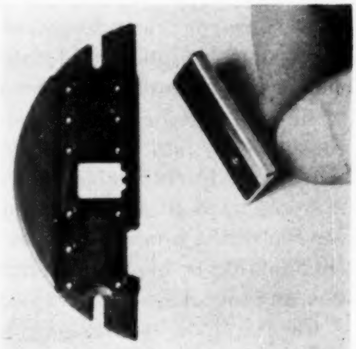

Fig. 2—Auricon aperture and pressure plates.

Like many other devices in the industry, the "Auricon-Pro" camera film gate has gone through years of evolution and redesign. These changes have been influenced by the fact that simplicity of design required the film to be confined with appreciable pressures throughout the entire intermittent cycle, and placed severe requirements upon materials used in the film-gate construction.

Within the past year Berndt-Bach redesigned the "Auricon-Pro" camera gate to permit the use of hard contact points in the aperture plate so located that these contacts do not touch either the picture or sound track area of the film emulsion. In the back pressure plate a single contact

is located directly behind the center of the aperture. The film is fully confined and in focus at the actual aperture area. The eleven aperture plate contacts are located to secure distribution of the pressure forces over the entire aperture plate, in addition to providing film support at the aperture opening and at the entering and leaving positions of the pulldown claw.

At the time of this redesign we believed the use of highly polished hard-chrome-steel balls offered a favorable material. Initial tests proved satisfactory, but it became evident that these balls in contact with film emulsions developed pits and corroded to an extent that nullified the advantages of their original mirror polish and hardness.

The hard-chrome-steel balls were then replaced with balls of a special stainless steel of the same diameter, to secure improved corrosion-resistant qualities. Realizing that these stainless-steel balls would be subject to surface abrasion from acetate film base and emulsion regardless of original fine surface finish, the balls were lapped and polished after assembly to provide a tiny flat on each and slightly increase the contact area. This application has produced the most satisfactory Auricon camera film gate thus far obtained with metals, and patent applications have been allowed on this construction.

Concurrently, investigation of the possible uses of industrial sapphire in this application was undertaken, since the redesign was based on an endeavor to secure point or very small area contacts of extremely hard, nonporous material located in emulsion areas which would not encroach on picture or sound track.

Sintered carbide materials, which offered excellent hardness and resistance to film abrasion, were ruled out on the two counts of porosity and unfavorable friction coefficient.

Application of industrial sapphire was contemplated from the inception of the program. Short of diamond, sapphire offers the best combination of hardness, nonporosity and friction coefficient qualities, and the additional advantage of a monocrystalline structure.

Clear sapphire balls of approximately $^3/_{32}$ inch in diameter were inserted in the Auricon-Pro camera gate. (There is no practical difference between the clear and the ruby-red sapphire, aside from color.) With the single-point ball contact of the back pressure plate directly behind the center of the aperture, no difficult sapphire-ball-mounting problem exists. However, with the eleven ball contacts of the aperture plate it is not only desirable that the multiple inserts cumulatively form a perfectly flat plane but, in the case of those im-

mediately surrounding the aperture, a must. This can be maintained by carefully pressing in the contacts to uniform height or, preferably from a production standpoint, by flat-finish lapping with fine diamond compound. In this case even a very slight lapping to produce a small polished flat on the spherical surface considerably increases the contact area and provides a safer margin for film gate pressure-plate loading.

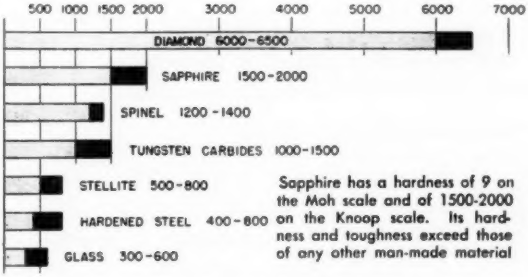

Fig. 3. Hardness chart.

PHYSICAL CHARACTERISTICS OF SAPPHIRE

Sapphire offers the motion picture industry some remarkable physical characteristics, the most favorable of which is its friction coefficient in relation to film. Use of the material has been limited to a very few applications in the industry, of which we might mention the use of sapphire jewel bearings and film-edge guides.

Table I will serve to suggest, merely on the basis of physical characteristics, where sapphire will find worth-while application. We see no need to suggest that sapphire indiscriminately replace existing components. Where no present vital problem exists there is little need to seek an immediate solution. However, in contemplating redesign of existing equipment, or development of new devices, the designer can hardly ignore consideration of so favorable an engineering material.

A note to the designing engineer would not be amiss, in calling to his attention that sapphire becomes a fragile material when subjected to shock of various natures. Sapphire subjected to severe mechanical shock might lead one to believe that data on compressive strength and elastic characteristics is in the nature of a snare and a delusion. We emphasize this despite personal tests wherein ruby jewels of 0.015 inch in thickness were placed on a steel plate and vigorously pounded with a pyralin hammer, without breakage.

TABLE I. SAPPHIRE PRODUCTS

(Technical Data)

Properties of Synthetic Sapphire

Chemical Formula—Al_2O_3
Melting Point—2050 °C–3722 °F
Crystal System—Hexagonal
Chemical Resistance—Not affected by any known chemical at room temperatures
Modulus of Rupture—59,000 to 125,000 pounds per square inch approximately
Compressive Strength—300,000 pounds per square inch
Water Absorption—0
Density, lb. per cubic inch—0.144
Specific Gravity (Water = 1)—3.99
Elastic Modulus—Steel—30,000,000
Sapphire—55,000,000
Refractive Index—1.757, 1.765
Thermal Conductivity—0.007 cal.sec.$^{-1}$ cm.$^{-1}$°C^{-1}
Thermal Coefficient of Expansion—3.3 × 10-6 per degree Fahrenheit average
Dielectric Constant—7.5–10.0
Stability on Aging—No change

Specific Heat

Silver	0.05
Copper	0.09
Steel	0.10
Glass	0.16
SAPPHIRE	0.18
Porcelain	0.26

Hardness and Toughness

	Hardness (Knoop Scale)	Toughness (Relative)*
Diamond	6,000–6,500	2
Boron Carbide	2,200	4
SAPPHIRE	2,000	3
Tungsten Carbide	1,000–1,500	2
Hard Chromium Plate	850–900	1
Stellite	500–800	1
Steel, Rockwell C65–67	791	1
Crystalline Quartz—Parallel to axis	710	
Perpendicular to axis	790	4
Steel, Rockwell C47	496	1
Fused Quartz	475	4
Crown Glass	420–470	5

*Comparative order of toughness, highest being number one.

Coefficient of Friction Against Steel

Sapphire	0.14
Graphite	0.16
Leaded Brass	0.19

Shock of another nature to which sapphire should not be subjected is thermal shock, or sudden changes in temperature. This should be taken into consideration when designing with a view to using the new metal-bonding techniques. Until recently, solder recommendations in connection with soldering metal-bonded sapphire shapes have been limited to low-temperature solders. However, silver soldering of metal-bonded sapphire shapes is becoming practical.

Extended research has been undertaken in the technique of flame forming and finishing of sapphire. In the process, sapphire is heated to a very high temperature in an oxidizing atmosphere and can be formed by "slipping" the planes of the crystal. In spite of very drastic deformation in shape the sapphire still maintains a monocrystalline character. During this operation the surface of the material flows to form a very high surface finish. Thus far, flame forming is limited to rod stock under 0.125 inch in diameter. Pigtail thread guides formed by 360-degree bends in sapphire rods offer an excellent illustration of the possibilities of flame forming.

Applications of sapphire to motion picture equipment are few in number and too limited to enable one to make an accurate estimate of the full worth of this newly advailable material at the present time. Friction coefficients, resistance to abrasion, hardness, physical stability, and other vital qualities have been demonstrated through applications in other industries. In sapphire we are dealing with an engineering material of known characteristics and increasing availability, in which the field of potential application is still largely unknown.

One of the most interesting potentials appears when we think of film as an abrasive textile, abrading to a greater or less degree each surface with which it comes in contact during its life span, and in turn being itself abraded through the deterioration of those same surfaces. The thought of introducing sapphire surfaces at critical or strategic locations along that film path then becomes interesting indeed.

Discussion

CHAIRMAN WATSON JONES: Are there any questions?

MR. SAUTER: With reference to precision bearings for mechanical engineering use, what class of accuracy compared to standard precision bearings could we obtain in ball bearings?

MR. CHRIS WAGNER: Balls are being made to an accuracy of twenty-five millionths sphericity and 0.0002 inch for diameter. The diameter tolerance could be reduced further if necessary for application in ball bearings.

MR. SAUTER: In high-speed work what type lubricant would you need?

MR. WAGNER: The practical value of sapphire in high-speed work is the elimination of lubricant. It will run dry in contact with steel races or with sapphire races.

MR. SAUTER: How does the cost compare with high-precision regular ball bearings?

MR. WAGNER: The cost is higher. In $^{1}/_{16}$ balls the cost is about sixteen cents per ball, and as the balls get larger the cost goes up. However, it does offer possibilities in engineering work where the ball bearings are subject to extreme speed or to corrosion.

Report of SMPE Standards Committee

By FRANK E. CARLSON, Chairman

General Electric Co., Nela Park, Cleveland

In his report[1] as retiring chairman of the Standards Committee, F. T. Bowditch offered several suggestions for improving the effectiveness of the Committee. Briefly, he proposed that the development of standards could most properly be done by the several engineering committees of the Society and that the past practice of organizing subcommittees of the Standards Committee to prepare such standards should be discontinued wherever possible. Further, he proposed that the Committee on Standards should be so organized that it functions primarily as a policy-making group, but it should also be competent to consider the over-all effect of standards proposals in relation to the industry and to related standards.

These recommendations were promptly adopted by the present chairman and, as a result, the Standards Committee has been functioning in substantially the manner envisioned by Bowditch. Since the new plan obviously called for close co-operation with each of the engineering committees and since the chairmen of such committees are obviously qualified in their respective fields, it was felt that a first step toward a representative policy-making group would be to invite these chairmen to serve as members of the Standards Committee. The second step was to include as members the chairmen of the several ASA sectional committees having interests closely related to the motion picture industry. A third and final step was to solicit the participation of the Motion Picture Research Council and of only a few of the many members of the Society who, either because of special knowledge or long experience with standardization problems, could be of outstanding assistance to the committee. The Engineering Vice-President approved this plan, and the present committee has been in operation since its appointment early in 1948.

The accomplishments of the present Committee are properly credited to the several engineering committees identified with the projects briefly described in the balance of this report.

Presented: As of December 31, 1949.

FILM DIMENSIONS

A Subcommittee on Cutting and Perforating Raw Stock had been in existence since November, 1945, under the chairmanship of Dr. E. K. Carver. Since that date the subcommittee has completed several assignments, but it was apparent that much standardization of film dimensions remained to be done. Accordingly, the Standards Committee recommended to the Engineering Vice-President the formation of an engineering committee to deal with such problems. In this particular field the Standards Committee has acted on the following:

1. Reaffirmed[2] the American Standard for cutting and perforating 35-mm negative raw stock (Z22.34–1944).
2. Recommended for adoption as standards by ASA two of three proposed 32-mm cutting and perforating standards which had been published[3] for a period of trial and criticism in the JOURNAL. Not approved was the third proposed standard, related to cutting and perforating 32-mm on 35-mm motion picture negative raw stock. It was tabled because several members were opposed to having nitrate stock perforated in this fashion because of the possibility of its being slit to 16-mm and used on conventional 16-mm projection equipment.
3. Referred back to the Film Dimensions Committee the proposed American Standard, "35-mm Motion Picture Combination Positive-Negative Raw Stock, Z22.1" which had been published[4] for a period of trial and criticism in the JOURNAL. Final action on this proposal has been deferred pending the outcome of additional tests of the suitability of the proposed perforations.

16-MM AND 8-MM MOTION PICTURES

The subject of standards relating to sprockets continues to be the most difficult problem in this category confronting the Committee. The entire Committee is in agreement as to the merits of the design practice described by Chandler, Lyman, and Martin[5] to insure good performance with film. The Committee, however, cannot agree that such a practice can properly become an American Standard. Accordingly, the Committee has asked for and obtained approval from the Board to publish an abridgement of the Chandler, Lyman and Martin paper in a format suitable for inclusion in the Standards binder of the Society as an SMPE recommendation on sprocket design. This abridgement is scheduled for publication in an early issue of the JOURNAL.

Concurrently, the Standards Committee has recommended the withdrawal of the following two standards relating to this subject which are now obsolete: (1) American Standard for 8-mm Motion Picture Film Eight Tooth Projector Sprockets (Z22.18–1941); and (2) American Standard for 16-mm Motion Picture Film Projector Sprockets (Z22.6—1941).

A subcommittee of the Standards Committee and, later, the 16-mm and 8-mm Motion Pictures Committee has been in the process of reviewing and revising the six present standards relating to 16-mm and 8-mm picture apertures. The Standards Committee has approved four proposed standards[6] to take the place of the present six standards and has recommended their adoption as standards by ASA and the rescinding of the two superfluous standards Z22.13–1941 and Z22.14–1941.

The 16-mm and 8-mm Motion Pictures Committee has also completed work on three new standards which the Standards Committee has approved for a period of trial and criticism. These three proposed standards have been published[7] in the JOURNAL and relate to:

1. Mounting threads and flange focal distances for lenses on 16-mm and 8-mm motion picture cameras.

2. A base point for focusing scales on 16-mm and 8-mm motion picture cameras.

3. Winding of 16-mm sound motion picture film.

The first two proposed standards are intended to replace war standards developed under the war procedures of the ASA for use of the Armed Services. The third proposal is intended to formalize a practice in use by film manufacturers for a number of years and which the SMPE, in 1941, adopted as a recommended practice.

A new standard relating to splices for 16-mm motion picture films will soon be published in the JOURNAL for a period of trial and criticism. This proposed standard, if adopted, will replace the two existing standards, Z22.24–1941 and Z22.25–1941, relating to silent and sound films respectively and is intended to apply only to projection films. The Standards Committee feels that a separate standard for negative films is also needed and the 16-mm and 8-mm Motion Pictures Committee has been asked to consider this matter.

The 16-mm and 8-mm Motion Pictures Committee has also proposed a revision of Z22.11–1941 relating to 16-mm motion picture projection reels. The Standards Committee is, at the present time,

reviewing this proposal and may approve it for publication in the JOURNAL for a period of trial and criticism.

PHOTOMETRIC CALIBRATION OF CAMERA LENSES

Since there is no engineering committee of the Society that is prepared to take over this project, it has continued to be handled by a subcommittee of the Standards Committee under the able chairmanship of Mr. Kingslake. A report of Mr. Kingslake's subcommittee has been recently published[8] in the JOURNAL and the subcommittee has been requested to prepare this material in a form suitable for consideration as a proposed standard.

OBSOLETE STANDARDS

It is obviously important that the Standards Committee not only encourage the processing of new standards beneficial to the industry but also recommend the withdrawal of old standards which have become obsolete or which, by their continued existence, impede progress. Accordingly, the following standards have been reviewed by engineering committees, and, as a result of their findings, the Standards Committee has recommended withdrawal: (1) American Recommended Practice for Motion Picture Film Sensitometry (Z22.26–1941); and (2) American Recommended Practice for Motion Picture Engineering Nomenclature (Z22.30–1941).

REFERENCES

(1) "Report of the Standards Committee," *Jour. SMPE*, vol. 51, pp. 230–241; September, 1948.

(2) "Standards recommendations," *Jour. SMPE*, vol. 52, p. 358; March, 1949.

(3) "Three proposed American Standards," *Jour. SMPE*, vol. 52, pp. 223–230; February, 1949.

(4) "Proposed American Standard," *Jour. SMPE*, vol. 52, pp. 447–452; April, 1949.

(5) "Proposals for 16-mm and 8-mm sprocket standards," *Jour. SMPE*, vol. 48, p. 483; June, 1947.

(6) "Proposed standards for 16-mm and 8-mm picture apertures," *Jour. SMPE*, vol. 52, pp. 337–348; March, 1949.

(7) "Proposed American Standards—16-mm and 8-mm," *Jour. SMPE*, vol. 53, pp. 293–300; September, 1949.

(8) "Report of lens calibration subcommittee," *Jour. SMPE*, vol. 53, pp. 368–378; October, 1949.

New American Standards

THE TWO TEST FILM STANDARDS that appear on the following pages were proposed initially and developed by the Motion Picture Research Council. After being subjected to careful study under the normal procedure of American Standards Association Sectional Committee on Motion Pictures Z22, they were approved for publication and have now been added to the list of available standards.

An up-to-date index listing these and several other changes made during the past year has just been prepared and copies are available to all who use motion picture standards for reference.

Within the last two or three weeks copies were sent free of charge to all whose names are on the Standards Mailing List. If you have one of the Society's "American Standards Binders" and have not yet received the green index dated January 1, 1950, send your name and address to Boyce Nemec, Executive Secretary, and your index will be sent by return mail.

The addresses of all who inquire will be placed on the Binder List to be notified each time new or revised standards are approved for publication.

A number of recent Proposals for Standardization and all of the American Standards shown in the index have been printed or reported upon in one or more of the following issues of the JOURNAL:

1946	April	page 284	1949	February	page 223
	September	258		March	337
1947	August	171		April	434
	December	547			& 447
1948	March	280		August	211
	November	534		September	293

American Standard

Sound Focusing Test Film for 35-Millimeter Motion Picture Sound Reproducers (Service Type)

ASA
Reg. U. S. Pat. Off.
Z22.61-1949

*UDC 778.5

1. Scope and Purpose

1.1 This standard describes a film which may be used for focusing the optical systems in 35-millimeter motion picture sound reproducers. The recorded frequency shall be suitable for use in the routine maintenance and servicing of the equipment.

2. Test Film

2.1 The film shall be a print from an original negative and shall contain a 7000-cycle, sinusoidal, variable-area or variable-density track recorded at 1 decibel below 100-percent modulation. The variation in power output level from the film shall be not more than ±0.25 decibel.

2.2 The sound track shall comply with American Standard Sound Record and Scanned Area, Z22.40-1946, and the film stock used shall be cut and perforated in accordance with American Standard Cutting and Perforating Dimensions for 35-Millimeter Motion Picture Raw Stock, Z22.36-1947, or any subsequent revision thereof.

NOTE: A test film in accordance with this standard is available from the Motion Picture Research Council or the Society of Motion Picture Engineers.

Approved February 4, 1949, by the American Standards Association, Incorporated.

Sponsor: Society of Motion Picture Engineers.

*Universal Decimal Classification

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American Standard

Buzz-Track Test Film for 35-Millimeter Motion Picture Sound Reproducers

ASA
Reg. U. S. Pat. Off.
Z22.68-1949

*UDC 778.534.4

1. Scope and Purpose

1.1 This specification describes a film which may be used for checking the lateral scanning slit placement of 35-millimeter motion picture sound reproducers.

2. Test Film

2.1 The test film shall be a direct positive recording or a print from an originally-recorded negative and shall contain 300-cycle and 1000-cycle square-wave tracks on either side of the central exposed strip as shown in Fig. 1.

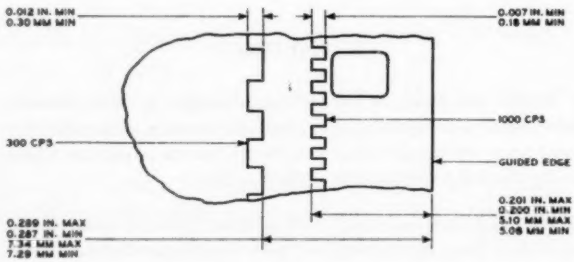

Fig. 1

2.2 The central exposed strip and the exposed portion of the two signal tracks shall have a minimum density of 1.4 and a maximum density of 2.0.

2.3 The film stock used shall be cut and perforated in accordance with the American Standard Cutting and Perforating Dimensions for 35-Millimeter Motion Picture Positive Raw Stock, Z22.36-1947, or the latest revision thereof approved by the American Standards Association, Incorporated.

2.4 The film stock used shall have a shrinkage of not more than 0.50 percent.

NOTE: A test film in accordance with this standard is available from the Motion Picture Research Council, or the Society of Motion Picture Engineers.

Approved May 23, 1949, by the American Standards Association, Incorporated.

Sponsor: Society of Motion Picture Engineers.

*Universal Decimal Classification

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New Officers of the Society

Members who were elected during the annual Society elections in 1949 took office on the first of January. So that Society members who have recently joined may become better acquainted with these men who are responsible for managing the affairs of the Society, here they are:

Engineering Vice-President

Fred T. Bowditch has been closely associated with Society administration for many years, having served several terms as a member of the Board of Governors. This year he vacates the second half of a two-year Governorship, in order to become Engineering Vice-President for 1950 and 1951; and, so that he may devote a major part of his time to the important engineering committee work of the Society, he has also resigned from the Chairmanship of Committee Z22, the Sectional Committee on Motion Pictures of the American Standards Association. Since last October Mr. Bowditch, John A. Maurer, outgoing Engineering Vice-President and Bill Deacy, Society Staff Engineer, have been reviewing committee appointments and projects, with an eye toward the easy transfer of responsibilities, as well as the gradual expansion of the work of our many technical committees.

Mr. Bowditch is Director of Illuminating Carbon Research for the National Carbon Company, Box 6087, Cleveland 1.

Financial Vice-President

Ralph B. Austrian moves from the office of Treasurer which he held in 1948 and 1949 to become Financial Vice-President for 1950–1951. He replaces David B. Joy, who retires from the Board of Governors this year after a number of years of very active service to the Society.

Long associated with the sound recording and theater equipment part of the motion picture industry, Mr. Austrian has more recently been active in the field of television. He is currently doing consulting work in television broadcasting and also in theater television. He may be reached at 25 West 54th St., New York 19.

Treasurer

Frank E. Cahill becomes Treasurer of the Society for 1950 and 1951, replacing Mr. Austrian. Having been a member of the Society for nearly twenty years, with many years of service on the Board of Gov-

ernors and on several engineering committees, Mr. Cahill is well known to the Society and to the motion picture industry. During the recent war, he was Executive Officer of Army Pictorial Service and at the end of the war, he reassumed his duties as Technical Director of Warner Bros. Circuit Management Corp., 321 West 44th St., New York 18.

Governors

Lorin D. Grignon begins his first term on the Board of Governors after a number of active years with the Pacific Coast Section of the Society. "Flicker in Motion Pictures" has long been a topic of major interest for Mr. Grignon and more recently he has been active in television film and theater television matters on the West Coast. He is an engineer in the Studio Sound Department at Twentieth Century-Fox Films, Inc., Box 900, Beverly Hills, Calif.

Paul J. Larsen was elected last year to his third successive term as a Governor of the Society. His interest in theater television continues although he is currently occupied with other matters. He may be reached at 508 S. Tulane St., Albuquerque, N.M.

William H. Rivers has served two one-year terms as Chairman of the Atlantic Coast Section of the Society, which made him an ex-officio member of the Board for 1948 and 1949. As a result, members in and near New York City are well acquainted with him. He now begins his first two-year term as an elected Governor and may be reached at Eastman Kodak Company, 342 Madison Ave., New York 17.

Edward S. Seeley was a Manager of the Atlantic Coast Section for a two-year term which ended in December, 1949, and he now becomes a Governor for 1950 and 1951. Having been Chief Engineer of Altec Service Corp. for a number of years, Mr. Seeley is well known in the audio-engineering and theater equipment fields. His office is at Altec Service Corp., 161 Sixth Ave., New York 13.

R. T. Van Niman has served two successive terms as Chairman of the Central Section, for 1948 and 1949. In 1948 he was elected to two Society offices: Central Section Chairman for 1949 and Society Governor for 1949 and 1950. He chose to resign the Governorship in order to devote more time to the work of the Section. He now retires from the Section Chairmanship and has once again been elected as a Governor, this time for 1950 and 1951. As a member of the sound committee for several years he was Chairman of the Subcommittee on Phototubes. He is a sound engineer for Motiograph, Inc., and may be reached at 4501 Washington St., Chicago 24.

John P. Livadary was elected in 1949 to fill a one-year West Coast Governorship vacancy. The unfilled position was left vacant by the resignation of S. P. Solow who in 1948 was elected to two Society offices and chose to retain the Chairmanship of the Pacific Coast Section. Mr. Livadary is a member and friend of the Society of long standing who now begins his first term on the Board. Having been Sound Director of Columbia Pictures for many years, he is active in the work of the Motion Picture Research Council and of our own sound committee, and may be reached at 4034 Cromwell Ave., Los Angeles 27.

Section Officers

The Atlantic Coast Section Chairman for 1950 is Edward Schmidt, Technical Representative for Reeves Sound Studio, 304 East 44th St., New York 17. The Secretary-Treasurer is Harry Milholland, head of the Tele-Transcription Department at Allen B. Du Mont Laboratories, Inc., 515 Madison Ave., New York 22.

Central Section Chairman is George W. Colburn, President of George W. Colburn Laboratories, 164 No. Wacker Drive, Chicago 6. The Secretary-Treasurer is C. E. Heppberger, Lighting Carbon Technical Specialist, National Carbon Company, Inc., 230 No. Michigan Ave., Chicago 1.

Pacific Coast Chairman is Charles R. Daily, Optical Engineer, Paramount Pictures, Inc., 5451 Marathon St., Hollywood 38, Calif. The Secretary-Treasurer is Vaughn C. Shaner, Technical Service, Eastman Kodak Company, 6706 Santa Monica Blvd., Hollywood 38, Calif.

Engineering Committees

In addition to appointing new chairmen for several of the Society's eighteen engineering committees, F. T. Bowditch, newly elected Engineering Vice-President, and Bill Deacy, Society Staff Engineer, have just completed an impressive schedule of engineering committee projects for 1950. Most of them are a continuation of work that was begun during 1949 or earlier, but several of the projects are entirely new. One example concerns a special leader for 16-mm television films that would replace the conventional "academy" leader that is generally not favored by television film users. One of the requirements of the

new leader is that it give an accurate "on the air" cue for both the television projector operator and the program director. This is a serious matter to television broadcasters since film must be cued to start on the second with no such liberal tolerances as are standard practice in theaters.

Another of the new projects, and one that was suggested by the Technical Editor of a motion picture trade magazine, has to do with possible standards or recommendations for air conditioning of theater auditoriums.

So that members may keep posted throughout the year on the current status of these and other projects, each issue of the JOURNAL for 1950 will review some of the work of several engineering committees. This is something new and Bill Deacy would appreciate comments on this method of reporting.

Frank E. Carlson of General Electric, Nela Park, Cleveland, has just been appointed Chairman of the Standards Committee for his second consecutive two-year term. In this issue of the JOURNAL he reports on changes made in the organization of the Standards Committee when he became chairman early in 1948, and on the accomplishments of the committee over the past two years. During that time the Standards Committee has served primarily as a policy-making body, supervising the Society's standardization activities and advising the Engineering Vice-President. A careful study of Mr. Carlson's report will give a good working knowledge of the way in which standards are developed; and his report should be of interest to members who either use these American Standards or participate in some phase of the Society's committee work.

The final result of almost any engineering project has in the past been either a specific formal standards proposal or a detailed committee report which, though generally not as concise as a standard, has served to document a particular chapter or phase of our engineering history. For some time we have needed an "in-between" type of document, less formal than a standard but more specific than the customary committee report. It should be a way of presenting committee recommendations as a series of reference publications on subjects that do not lend themselves readily to standardization under rigid ASA procedures. To fill this gap, the Society's Board of Governors recently approved publication of "Society Recommendations." A description of this new type of publication is part of the report of the President for 1949 that appears in this issue.

1950 Nominations

All Active, Fellow and Honorary members may recommend candidates for the ten vacancies on the Board of Governors which will occur on December 31, 1950. Suggestions should be mailed early so that they will certainly be in the hands of the Nominating Committee prior to May 1, 1950. They may be addressed to the Chairman or to any of the members of the Committee:

D. E. Hyndman, *Chairman*
Room 626, 342 Madison Ave., New York 17.

Herbert Barnett
General Precision Equipment Corp.
63 Bedford Road, Pleasantville, N.Y.

F. T. Bowditch
Research Laboratories
National Carbon Company
Box 6087, Cleveland 1.

F. E. Cahill, Jr.
Warner Bros. Pictures, Inc.
321 West 44th St., New York 20.

R. E. Farnham
General Electric Company
Nela Park, Cleveland 12.

G. R. Giroux
Technicolor Motion Picture Corp.
6311 Romaine St., Los Angeles 28, Calif.

A. N. Goldsmith
597 Fifth Ave., New York 17.

T. T. Goldsmith
Allen B. Du Mont Laboratories
2 Main Ave., Passaic, N.J.

K. F. Morgan
Western Electric Company
6601 Romaine St.,
Hollywood 38, Calif.

The Board members whose terms expire at the end of this year are:

President, E. I. Sponable
Executive Vice-President, Peter Mole
Editorial Vice-President, C. R. Keith
Secretary, R. M. Corbin
Convention Vice-Pres., W.C. Kunzmann
Governor (East), Herbert Barnett
Governor (East), (vacant)
Governor (West), K. F. Morgan
Governor (West), J. P. Livadary
Governor (West), N. L. Simmons

Society Awards for 1950

Each year the Society considers candidates for five awards on the basis of the qualifications outlined briefly here. Further details concerning these awards are published in the April issue of the Journal each year for the information of members who may not be familiar with them. Suggestions or questions concerning these matters may be addressed to the chairman of any of the award committees or to the Executive Secretary at Society Headquarters in New York.

Fellow Award

Members in the Active grade who by their " . . . proficiency and contributions have attained outstanding rank among engineers or executives of the motion picture industry" may be proposed and con-

sidered as possible award nominees by the Fellow Award Committee. Such proposals will be received only from present Fellows of the Society and should be addressed to Loren L. Ryder, Committee Chairman and Past-President of the Society. His address is: Paramount Pictures, Inc., 5451 Marathon St., Hollywood 38, Calif.

Honorary

The Honorary Membership Award is a distinction given to pioneers who have contributed inventions of basic importance to the industry or whose contributions have made possible better production, administration or utilization of motion pictures. Recommendations for the Honorary Membership Award may be submitted by any member of the Society and must be endorsed by at least five Fellows, who are required to set forth in writing their knowledge of the accomplishments which appear to justify presentation of the Award. Such recommendations must be addressed to the Honorary Membership Committee Chairman, Gordon A. Chambers, Motion Picture Film Dept., Eastman Kodak Company, 343 State St., Rochester 4, N.Y.

Journal Award

The Journal Award is presented annually at the Fall Convention of the Society to the author of the most outstanding paper originally published in the JOURNAL of the Society during the preceding calendar year. Technical merit, originality and excellence of presentation are three major considerations. The authors of papers of nearly equivalent merit often receive Honorable Mention. The Journal Award Committee, appointed by the President, is now under the Chairmanship of Dr. C. R. Daily, who will shortly be receiving from members of his Committee, their recommendations for the most outstanding paper for 1949. His address is: 5451 Marathon St., Hollywood 38, Calif.

Samuel L. Warner Memorial Award

Each year the President appoints a Samuel L. Warner Memorial Award Committee to consider candidates for the Award. Preference is given to inventions or developments occurring in the last five years, and also to inventions or developments likely to have the widest and most beneficial effect on the quality of reproduced sound and picture. The Award is made to an individual and may be based upon his contributions of the basic idea involved in the particular development being considered and also on his contributions toward the practical working out of the idea. The purpose of the Award is to encourage the development of new and improved methods or apparatus designed for sound on film motion pictures, including any step in the process.

The present Chairman of the Committee is W. V. Wolfe, Motion Picture Research Council, 1421 North Western Ave., Hollywood 27, Calif.

Progress Medal Award

Written recommendations for candidates for the Progress Medal Award may be submitted by any member of the Society, giving in detail the accomplishments which appear to justify consideration. Qualifications should include invention, research, or development which has resulted in a significant advance in the development of motion picture technology and should be seconded in writing by any two Fellows or Active members of the Society, after which the recommendations must be filed with the Chairman of the Committee. For 1950, the Chairman is Dr. J. G. Frayne, Westrex Corp., 6601 Romaine St., Los Angeles 38, Calif.

Society Announcements

Membership Directory 1950

The Society's *Membership Directory* for 1950 is scheduled for early publication, so members are urged to reply promptly to the questionnaire-envelope enclosed with the 1950 membership dues statement. Since the *Directory* is published every two years, addresses and company affiliations must be corrected now, or stand uncorrected till 1952. Please send yours in now if it has not already been mailed.

Section Meetings

The first regular meeting of the *Atlantic Coast Section* in 1950 is scheduled for 7:30 P.M., January 18, at the RKO Pathé Studios, 105 East 106th St., New York City. Ed Schmidt, Section Chairman, reports that Drs. E. B. Jennings and A. B. Weiss will describe and demonstrate the new du Pont release positive color film. This is to be a somewhat condensed version of several du Pont papers on the new Type 275 film that were presented during the 66th Convention in Hollywood last October.

Attendance should be excellent since this will be the first opportunity that many East Coast members of the Society have had to look over this much discussed new film.

The *Central Section* meets at 8:00 P.M., January 12, in the small auditorium of the Western Society of Engineers, 84 E. Randolph St., Chicago 1. Current trends in film distribution will be dsucussed by Thomas McConnell, Chicago attorney and authority on that phase of the motion picture industry.

This will be a double feature meeting, with a second paper presented by George W. Colburn, describing a Double System 16-mm Projector. Educational and

advertising film producers who work exclusively with 16-mm films should be greatly interested, since Mr. Colburn will describe the modification of a conventional 16-mm projector which enables it to reproduce separate films for picture and sound track.

67th Convention

Plans are well underway for the 67th Society Convention to be held at the Drake Hotel in Chicago, April 24–28th. Members and their guests who plan to attend will be assured of adequate hotel accommodations since many rooms have been set aside by the hotel. These and other arrangements have already been made by Bill Kunzmann, our perennial Convention Vice-President. The Papers Program is already beginning to take form and the Papers Committee is hard at work.

An advance schedule of convention events, with hotel room reservation forms, will be mailed to all members about March 1. The Papers Committee expects to mail, about the last week in March, the Tentative Program listing all papers then scheduled. Authors who expect to present papers should ask the nearest Papers Committee Vice-Chairman for their Author's Forms. Copies of the Author's Form, together with a 100-word abstract of each paper should be sent to R. T. Van Niman in Chicago, so that the paper can be scheduled in time for the Tentative Program.

PAPERS COMMITTEE

N. L. Simmons, *Chairman*
6706 Santa Monica Blvd.,
Hollywood, Calif.

Vice-Chairmen:

J. E. Aiken
116 N. Galveston St., Arlington, Va.

L. D. Grignon
20th Century-Fox Films Corp.,
Beverly Hills, Calif.

E. S. Seeley
Altec Service Corp.,
161 Sixth Ave., New York 13, N.Y.

R. T. Van Niman
4501 Washington Blvd.,
Chicago 24, Ill.

H. S. Walker
1620 Notre Dame St., W.,
Montreal, Que., Canada

The Editor

This month's masthead shows for the first time our new Editor — Vic Allen, who joined us late in November. In previous experience as Production Manager for Interscience Publishers, he put into production Bill Offenhauser's book, *16-Mm Sound Motion Pictures*. He is well acquainted with the Society's printer, Mack Printing Company, in Easton, Pennsylvania, having handled several thousand pages printed yearly by Mack for Interscience. Before joining Interscience, he was Managing Editor of the *Journal* of the American Water Works Association. He began his technical editing on *The Foundry* magazine of Penton Publishing Company in Cleveland while a "co-operative" student from Antioch College. He has contributed to the publishing and printing field by active membership in the American Institute of Graphic Arts and by articles on such subjects as: various methods of typesetting tabular matter; two-column format for technical books; and methods of drafting technical illustrations.

Book Reviews

Acoustic Measurements, by Leo L. Beranek

Published (1949) by John Wiley & Sons, 440 Fourth Ave., New York 16. 896 pp. + 17 pp. index + VII pp. 519 illus. $6 \times 8^3/_4$ in. Price, $7.00.

This much needed book is a comprehensive collection of techniques and of tables of constants which the acoustic engineer requires for measurements and calculations. Of interest is a brief history of acoustic measuring instruments; and of reference value is a glossary of terminology. Dr. Beranek presents the solutions of the sound wave equations in various forms, with complete data on the velocity and attenuation in a great variety of media including effects of wind, jungle growth, etc.; and he also gives the experimental and calculated diffraction effects due to variously shaped bodies placed in the path of a plane.

Then follows an excellent treatise on techniques of calibrating microphones as standards for measuring sound pressures with particular emphasis on the reciprocity method. The methods generally used for measuring frequency are clearly presented with some good photographs of commercial instruments available

The chapter on the principles of calibrating pure tone audiometers is timely because of current efforts to develop specifications for a standard audiometer. The author discusses various types of meters for measuring quantities related to sound intensity such as peak meters, V. U. meters, level recorders, RMS meters, and also meters for analyzing transient and steady sounds into various sorts of components. The basic tests for the efficiency of communication systems to transmit speech are itemized and described, such as methods of measuring frequency and nonlinear response characteristics, repetition counts, syllable, word, and sentence articulation tests, and threshold measurements of received speech.

Methods are given in detail for testing the three basic elements of a communication system: the microphone, the line (including amplifier), and the headphone or loudspeaker. In each case the author has outlined the method of testing the frequency response, the power efficiency, the impedance, the nonlinear distortion, and overload capacity. With the discussion on loudspeakers there is a useful set of curves for determining power rating to give satisfactory loudness of speech or music in rooms of any size and treatment. There is one chapter on real voice testing methods of determining response characteristics of microphones and earphones. It is shown how these principles can be applied in a convenient form for testing the important characteristics of hearing aids. Methods of making articulation tests are outlined together with lists of syllables, of words, and of sentences, including the P. B. and Spondee tests.

The last three chapters are devoted to measurements of the acoustic properties of rooms, including the various methods of measuring the absorption properties of materials for treatment of such rooms. References throughout the book are numerous and should permit a student to pursue very satisfactorily any special phase. Many engineers will be grateful to Dr. Beranek for bringing together in such a convenient form so much technical information bearing on acoustic measurements.

Harvey Fletcher
(Columbia University)
5 Westminster Rd.
Summit, N.J.

Painting with Light, by John Alton

Published (1949) by Macmillan, 60 Fifth Ave., New York 11. 191 pp. + XIV pp. 292 figs. $7^3/_4 \times 10^1/_4$ in. Price, $6.00.

It has been said that the mechanical techniques of an art should be learned, then forgotten. More properly stated, they should become an unconscious part of the work of an artist. The author of *Painting with Light* frankly describes the techniques and devices he uses to obtain his effects. He does not assume that a novice may become a Director of Photography by reading his book and studying the copious layouts and illustrations, but he does describe his work with a straightforwardness that is refreshing as well as instructive.

While the book may seem to be an oversimplification of a very complicated art form to his brother workers in motion picture photography, it will serve as a means of conveying some of the problems of the cinematographer to many other departments of the industry, as well as to the associated organizations which design and manufacture equipment and materials for the industry.

The motion picture industry has a language of its own for describing the various workers and accoutrements used in motion picture set lighting and the book acts as an interpreter for the uninitiated.

The various types of lamps and lighting control equipment are described and illustrated. Lamp placement and manipulation are explained and illustrated with layouts as well as with photographs of the end results.

Chapters cover both indoor and outdoor photography, the close-up, long-shot, process work, and miniatures. For the most part, the author does not deviate from his subject and, while some of his techniques such as the "testlight" are not universal, he has spared neither time nor expense to cover the subject as completely as possible in so far as black and white photography is concerned, from his own viewpoint and within the covers of one book.

John W. Boyle, A.S.C.
Director of Photography
$139^1/_2$ So. Doheny Drive
Los Angeles 48, Calif.

Feininger on Photography, by Andreas Feininger

Published (1949) by Ziff-Davis, 350 Fifth Ave., New York 1. 409 pp., 360 illus. (approx.), 50 charts (approx.). $8^1/_2 \times 11$ in. Price, $15.00.

It is rare that a reviewer for a technical journal can go all out in praise of a basic book on photography with no fear that he is exposing himself to criticism. But this book is one that even the astute technician will consider well done for the purpose intended.

Mr. Feininger has put down for the amateur and professional still photographer what his 20 years of experience have shown to be essential to good picture making. Although he de-emphasizes matters of a strictly technical nature, he advocates systematic working methods based on fact and not folly. In reading the text one cannot help but be impressed by the unusually clear and, for the most part, accurate, insight into technical matters that the author has gained from his experience. It even appears that he may have studied the better technical literature to a greater extent than he recommends.

The book covers the subject thoroughly in 16 chapters. Little time is wasted anywhere in getting to the point, for the author is no believer in secrets or mystery in the photographic process; but he does stress that technical knowledge alone will never make a good photographer. This requires an "eye" for pictures which you either do or do not have. This attitude explains why Part I on technique consists of but seven chapters, whereas Part II on the art of making a photograph contains nine chapters.

Little would be gained by giving the usual list of chapter headings. The real value in the book will be found only in reading it page by page. It is highly recommended, especially to the motion picture engineer who seldom takes pictures, but who now and then gets the yen to "show up those guys at *Life*." Here's your chance, for Feininger, one of *Life's* most famous and able photographers, has left very little unsaid.

Lloyd E. Varden
Pavelle Color Inc.
533 West 57th St.
New York 19

The Complete Projectionist, by R. Howard Cricks

Published (1949) by Odhams Press, 6 Catherine St., London, W.C. 2. 335 pp. + 38 pp., including 14-page index. 209 illus. + tipped-in folded insert. $5 \times 7^1/_2$ in. Price, 10/- post free.

This work, obviously intended as a handbook for British projectionists, covers projection from every angle. By virtue of the fact that the author does cover the entire scope of the craft in 335 pp., comprehensive description of any single phase of projection is necessarily lacking. The numerous tables, charts, and illustrations are extremely well presented and will prove valuable to any projectionist or projection engineer.

Mr. Cricks' inclusion of television and several experimental developments will prove interesting to the craft as a whole. His chapters on projection practices in other than theater locations (process projection, 16-mm projection, etc.) are more descriptive of the job than of the technical operation of the equipment.

Despite the fact that data on equipment, rules, and regulations are necessarily limited to the British, the work will prove an informative addition to the library of any member of the craft.

Merle Chamberlin
Supervisor of Projection
Metro Goldwyn Mayer Studios
Culver City, Calif.

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Current Literature

THE EDITORS present for convenient reference a list of articles dealing with subjects cognate to motion picture engineering published in a number of selected journals. Photostatic or microfilm copies of articles in magazines that are available may be obtained from The Library of Congress, Washington, D.C., or from the New York Public Library, New York, N.Y., at prevailing rates.

American Cinematographer

vol. 30, no. 9, September, 1949

The Garutzo Lens in Motion Picture Photography (p. 320) R. M. NEWBOLD

Eclair Camerette Makes U.S. Debut (p. 321) B. BERG

Source Lighting (p. 324) C. LORING

Teaching Speech with 16-mm Movies (p. 330) R. W. STANMYRE

vol. 30, no. 10, October, 1949

They Do it with Infra-Red! (p. 360) LEIGH ALLEN

The Magic of Montage (p. 361) HERB A. LIGHTMAN

Balancing Television Camera Tubes (p. 362) RALPH LAWTON

vol. 30, no. 11, November, 1949

Lighting Translucent Backings (p. 398) L. GARMES

Signal System (p. 402) L. ALLEN

vol. 30, no. 12, December, 1949

New Speed for Films (p. 440) L. ALLEN

A 16-mm Sound Camera for the Home Movie Maker (p. 444) G. B. LEWIS

British Kinematography

vol. 15, no. 2, August, 1949

Developments in Magnetic Sound-on-Film Recording

Pt. I, Magnetic Sound and the Film (p. 37) O. K. KOLB

Pt. II, Magnetic Recording in Film Production (p. 47) N. LEEVERS

Pt. III, Performance Data of Magnetic Coatings (p. 50) A. TUTCHINGS

Demonstration of Sub-Standard Kinematograph Equipment

Danson Projector D23 (p. 54) W. LACEY

Debrie D16 Projector with Arc Lamp (p. 55) T. A. BARTLETT

Long-Running Projector with Mercury Lamp (p. 55) P. J. ORAM

M. R. Type 356 Cine-Flash (p. 56) H. K. BOURNE

"Brook" Continuous Projector (p. 57) H. S. HIND

vol. 15, no. 3, September, 1949

Closed Sequence Control Systems (p. 75) E. B. PEARSON and A. PORTER

The Application of Music to Films (p. 86) H. CLIFFORD

vol. 15, no. 4, October, 1949

Thirty Years of British Film Production (p. 105) M. BALCON

Current Practice in 16-mm Sound Printing (p. 116) M. V. HOARE

vol. 15, no. 5, November, 1949

Independent Frame Film Production:

I. Notes on a Production Technique (p. 141) K. BELLMAN

II. Progress Report on Independent Frame (p. 150) D. WILSON

Screen Illumination with Respect to Optics and Arc Characteristics (p. 155) A. G. DUERDOTH

Electronics

vol. 22, no. 12, December, 1949

New Directions in Color Television (p. 66)

Dot Systems of Color Television, Pt. 1 (p. 88) W. BOOTHROYD

International Photographer

vol. 21, no. 9, September, 1949

Light Can be Packaged (p. 20), A. WYCKOFF

International Projectionist

vol. 24, no. 9, September, 1949

Lens and Film Factors Affecting Focus, Pt. 2 (p. 7) R. A. MITCHELL

The 'Arcon' Projection Arc Monitor (p. 10) V. G. MATHISEN

New Series of Lenses for 16-mm Professional Projection (p. 16) A. E. NEUMER

vol. 24, no. 11, November, 1949

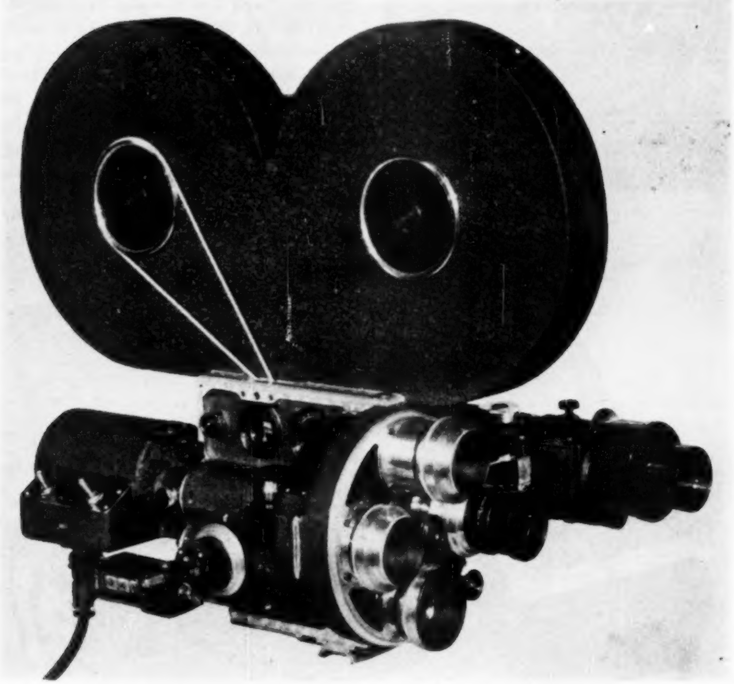
The 35-mm Projection Positive Film (p. 8) R. A. MITCHELL

Theatre Television: What, How and When (p. 12) J. E. MCCOY and H. P. WARNER

Film Fire Characteristics (p. 16) R. D. MARKS

New Products

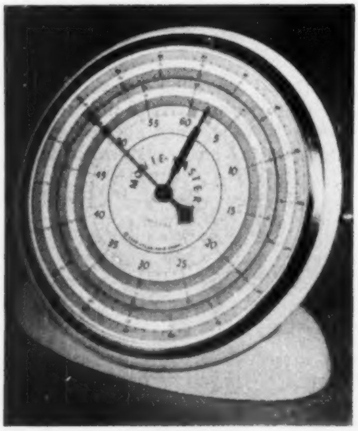
Further information concerning the material described below can be obtained by writing direct to the manufacturers. As in the case of technical papers, publication of these news items does not constitute endorsement of the manufacturer's statements nor of his products.



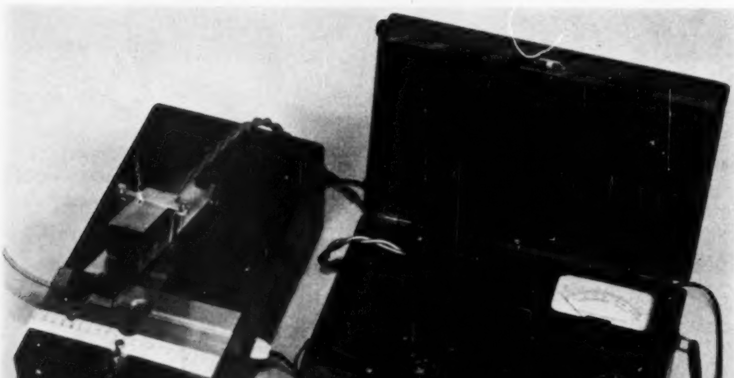
The Bell & Howell Design 2709 16-mm Camera is B&H's answer to the growing demands of the professional 16-mm field. It is an adaptation of the B&H Design 2709 Standard Camera (35-mm), with these reported features: (1) a 4-lens turret designed to permit the use of all the standard professional lenses; (2) a fixed-pilot-pin film movement mechanism similar to the B&H Unit "I"; (3) a 170° adjustable shutter with automatic dissolve; and (4) adaptability of stop-motion motor for one-, two- or three-frame operation.

The 200-, 400- and 1000-ft standard B&H (35-mm) magazines may be adapted to the 16-mm size by double flanges, rollers and cores.

Information is available from the Professional Equipment Div., Bell & Howell Co., 7100 McCormick Rd., Chicago 45.



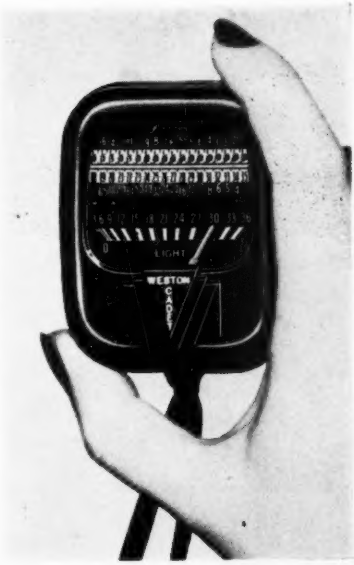
The Movie Master is a new timepiece manufactured by Atlas Time Corp., 2 West 47th St., New York 19. A forerunner of the Movie Master timer was the stop watch and timer made by Moss and Robinson, a subsidiary of Atlas Time Corp. The new timer has the same general features: three outer scales dividing the minute into 90 parts; three inner scales dividing the minute into 36 parts; and an extreme inner scale or minute track dividing the minute into 60 sec. It denotes in the first three minutes which of the colored scales of either 35- or 16-mm is in use. It has a $5^1/_2$-in. dial and stands on a table. The price is $12.50.



This Densitometer has been developed by the Photovolt Corp., 95 Madison Ave., New York 16, and is fully described in that firm's Bulletin No. 245. It is a photoelectric instrument designed to cover the transmission density range from 0 to 5.0. The range from 0 to 2.0 is direct reading, while other ranges may be selected by the operator and involve the use of an addition factor.

The densitometer is provided with a traveling film guide that accommodates both 16- and 35-mm film with the sound track always in register with an illuminated slit 0.020 in. wide. It also "reads" Eastman IIb Sensitometer strips and the smaller strips from the Eastman Processing Control Sensitometer, replacing more elaborate and more expensive equipment which in the past has been used for making these measurements on black-and-white films.

The Weston Cadet is a new exposure meter designed especially for travelers and casual photographers who want a small, easy-to-use meter. Its list price is $21.50. It is made by the Weston Electrical Instrument Corp., 617 Frelinghuysen Ave., Newark 5, N.J. Though small enough to fit into a vest pocket or purse, it is equipped with the Weston instrument movement and photronic cell, and is designed to give accurate shutter and diaphragm settings for all general amateur photography with either still or motion picture cameras, and for both black-and-white and color film. The Weston Cadet can be used for measuring incident light by using a translucent light collector which is pivoted on the back of the meter.



Meetings of Other Societies

March, 1950

Institute of Radio Engineers National Convention	March 6 through March 9 New York, New York
Optical Society of America Winter Meeting	March 9 through March 11 New York, New York

May, 1950

Armed Forces Communications Association Annual Meeting	May 12 New York City and Long Island City May 13 Fort Monmouth, New Jersey

June, 1950

Acoustical Society of America	June 22–24 State College, Pennsylvania

SMPTE Officers and Committees: The names of Society Officers and of Committee Chairmen and Members are published annually in the April issue of the Journal. Changes and corrections to these listings are published in the September Journal.

The Blue Comet Boom Light has been developed by Mole-Richardson Co. of Hollywood, Calif., to supply flexible illumination in commercial, motion picture and television studios. A new feature described by the manufacturer is the light-weight Blue Zephyr baby spot, with attached full-size diffusion frame and rotating barn doors, plus direct-action focusing with graduated scale. The lamp head is interchangeable with boom or the included auxiliary stand. To facilitate handling and transporting, the stand and boom legs are designed to fold flat, and the stand is strongly constructed with positive locking fittings and 3-in. rubber-tired casters with locking feet. The stand is reported not to tip even when operated at a y fully extended position, and the stand and boom arm are designed for easy extension, with an air-retainer brake in the boom stand to permit smooth, quiet adjustment of height.

SMPTE HONOR ROLL

By action of the Board of Governors, October 4, 1931, this Honor Roll was established for the purpose of perpetuating the names of distinguished pioneers who are now deceased.

Louis Aimé Augustin Le Prince	Edwin Stanton Porter
William Friese-Greene	Herman A. DeVry
Thomas Alva Edison	Robert W. Paul
George Eastman	Frank H. Richardson
Frederic Eugene Ives	Leon Gaumont
Jean Acme Le Roy	Theodore W. Case
C. Francis Jenkins	Edward B. Craft
Eugene Augustin Lauste	Samuel L. Warner
William Kennedy Laurie Dickson	Louis Lumiere
	Thomas Armat

HONORARY MEMBERS

Lee de Forest	A. S. Howell

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television, with its important additional sense of immediacy. True, television pictures are perhaps crude when compared with today's professional motion pictures, but they will not always remain so, and just as your Society has been a leader in the coordination of the development of, and setting up standards for, motion pictures, so is there a similar job to be done in television. Your recent vote to include "Television" in the name of your Society recognizes this need, as well as the fact that in certain regions the interests of the television and motion picture engineers coincide. Each can learn much from the other.

Beginning with this issue, the *Journal* will contain more and more articles of direct and immediate interest to television engineers; it is to be hoped that they will find their membership sufficiently rewarding so that they will become energetic in their support of the Society and its aims.

So in this — our new *Journal*, our new year, our new half century — we have new opportunities to prove our worth.

E. I. Sponable
President

Sustaining Members

OF THE

SOCIETY OF MOTION PICTURE AND TELEVISION ENGINEERS

Altec Companies
Ampro Corporation
Ansco Corporation
Audio Productions, Inc.
Bausch & Lomb Optical Co.
Bell & Howell Co.
Bell Telephone Laboratories, Inc.
Bijou Amusement Co.
Blumenfeld Theaters
J. E. Brulatour, Inc.
Buensod-Stacey, Inc.
Burnett-Timken Research Laboratories
W. S. Butterfield Theaters, Inc.
Byron, Inc.
The Calvin Company
Century Circuit, Inc.
Cinecolor Corp.
Cineffects, Inc.
Geo. W. Colburn Laboratory, Inc.
Consolidated Film Industries, Inc.
Coronet Instructional Films
DeLuxe Laboratories, Inc.
E. I. du Pont de Nemours & Co.
Eastman Kodak Company
Fabian Theaters
Max Factor & Co.
Jerry Fairbanks, Inc.
General Electric Company
Guffanti Film Laboratories, Inc.
Jam Handy Organization, Inc.
Hertner Electric Co.
Hunt's Theatres
Interboro Circuit, Inc.
International Projector Corp.
Interstate Circuit, Inc.
Kollmorgen Optical Corp.
March of Time
J. A. Maurer, Inc.
Mitchell Camera Corp.
Mole-Richardson, Inc.
Motiograph, Inc.
Motion Picture Association of America, Inc.
- Allied Artists Productions, Inc.
- Columbia Pictures
- Loew's, Inc.
- Paramount Pictures, Inc.
- Republic Picture Corp.
- RKO-Radio Pictures, Inc.
- Twentieth Century-Fox Film Corporation
- Warner Brothers Pictures

Movielab Film Laboratories, Inc.
Natco, Inc.
National Carbon Co., Inc.
National Cine Equipment, Inc.
National Theaters Amusement Co., Inc.
Neighborhood Theatre, Inc.
Pathé Laboratories, Inc.
Premier Operating Corp., Ltd.
Producers Service Co.
Projection Optics Co., Inc.
Prudential Circuit
Radio Corporation of America, RCA Victor Division
J. Arthur Rank Organization of Canada, Ltd.
Reeves Sound Studios, Inc.
SRT Television Studios
Technicolor Motion Picture Corp.
Terrytoons, Inc.
Theatre Owners of America, Inc.
Titra Film Laboratories, Inc.
United Amusement Corp., Ltd.
Universal Pictures Co.
Victor Animatograph Corp.
Western Electric Company, Inc.
Westinghouse Electric Corp.
Westrex Corp.
Wilding Picture Productions, Inc.